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MANUFACTURING
METHODS &
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**PROJECT SUMMARY
REPORTS**

(RCS DRCMT-302)

PREPARED BY

JUN 81

**USA INDUSTRIAL BASE ENGINEERING
ACTIVITY**

MANUFACTURING TECHNOLOGY DIVISION

ROCK ISLAND, ILLINOIS 61299

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DEPARTMENT OF THE ARMY
US ARMY INDUSTRIAL BASE ENGINEERING ACTIVITY
ROCK ISLAND, ILLINOIS 61299

REPLY TO
ATTENTION OF:

DRXIB-MT

14 JUL 1981

SUBJECT: Manufacturing Methods and Technology Program
Project Summary Report (RCS DRCMT-302)

SEE DISTRIBUTION (Appendix II to Inclosure 1)

1. In compliance with AR 700-90, C1, dated 10 March 1977, the Industrial Base Engineering Activity (IBEA) has prepared the inclosed Project Summary Report.
2. This Project Summary Report is a compilation of MMT Summary Reports prepared by IBEA based on information submitted by DARCOM major subordinate commands and project managers. These projects represent a cross-section of the type of efforts that are being conducted under the Army's Manufacturing Methods and Technology Program. Persons who are interested in the details of a project should contact the project officer indicated at the conclusion of each individual report.
3. Additional copies of this report may be obtained by written request to the Defense Technical Information Center, ATTN: TSR-1, Cameron Station, Alexandria, VA, 22314.

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J. R. GALLAUGHER
Director
Industrial Base Engineering Activity

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This report contains summaries of 105 projects that were completed under the Army's Manufacturing Methods and Technology (MMT) Program. The MMT program was established to upgrade manufacturing facilities used for the production of Army Materiel. The summaries highlight the accomplishments and benefits of the projects and the implementation actions underway or planned. Points of contact are also provided for those who are interested in obtaining additional information.		

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INTRODUCTION

Background

The Manufacturing Methods and Technology (MMT) Program was established to upgrade manufacturing facilities used for the production of Army materiel, and as such, provides direct support to the Industrial Preparedness Program. The Manufacturing Methods and Technology Program consists of projects which provide engineering effort for the establishment of manufacturing processes, techniques, and equipment by the Government or private industry to provide for timely, reliable, economical, and high-quality quantity production means. The projects are intended to bridge the gap between demonstrated feasibility and full-scale production. The projects are normally broad based in application, are production oriented, and are expected to result in a practical process for production. The projects do not normally include the application of existing processes, techniques, or equipment to the manufacture of specific systems, components, or end items, nor do they apply to a specific weapon system development or a product improvement program.

MMT Program Participation

MMT Programs are prepared annually by DARCOM major subordinate commands. These programs strive for the timely establishment or improvement of the manufacturing processes, techniques, or equipment required to support current and projected programs.

Project proposals (Exhibits P-16) are submitted to the appropriate MMT Program Office. A list of offices is provided in Appendix I. Additional information concerning participation in the MMT Program can be obtained by contacting an office listed or by contacting Mr. James Carstens, AUTOVON 793-5113, or Commercial (309) 794-5113, Industrial Base Engineering Activity, Rock Island, IL 61299.

In anticipation of the lengthy DOD funding cycles, projects must be submitted in sufficient time for their review and appraisal prior to the release of funds at the beginning of each fiscal year. Participants in the program must describe manufacturing problems and proposed solutions in Exhibit P-16 formats (see AR 700-90, 4 August 1975, for instructions). Project manager offices should submit their proposals to the command that will have mission responsibility for the end item that is being developed.

Contents

This report contains summaries of 105 completed projects that were funded by the MMT Program. The summaries are prepared from Project Status Reports (RCS DRCMT-301) and Final Technical Reports submitted by organizations executing the MMT projects. The summaries highlight the accomplishments and benefits of the projects and the implementation actions under way or planned. Points of contact are also provided for those interested in obtaining additional information.

The MMT Program addresses the entire breadth of the Army production base and, therefore, involves many technical areas. For ease of referral, the project summaries are grouped into six technical areas. The technical areas are CAD/CAM, Electronics, Inspection and Test, Metals, Munitions, and Non-Metals.

The Summary Reports are prepared and published for the Office of Manufacturing Technology, DARCOM, by the Manufacturing Technology Division of the Army Industrial Base Engineering Activity, (IBEA) in compliance with AR 700-90, Cl. The report was compiled and edited by Mr. Andrew Kource, Jr. and ably assisted by Mrs. Eileen Griffing with the typing and graphics arrangements.

ACHIEVEMENTS

This section contains abstracts of the key project achievements in this report. Attention is being focused on these projects because of significant benefits which are manifested through either technological advancements, cost reductions, or safety. This listing is not inclusive of all beneficial projects. Whether a project is beneficial or not depends upon one's needs. Therefore, even though the abstract of a project does not appear in this section, the reader should examine the body of this report for results that may suit his particular requirements.

TECHNOLOGICAL ADVANCEMENTS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
377 3169	Automatic Optical Inspection for Printed Circuit Boards and Components (CAD/CAM)	11

An automated, computer-controlled inspection system for populated printed wiring boards was designed and fabricated as a production prototype. The prototype laser scanner has the capability of inspecting boards for the majority of defects commonly encountered in PCB manufacturing at rates of 25 components per second.

677 7707	Automated Process Control for Machining (CAM)	18
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This project established a computerized metal cutting matrix for machining operations and workpiece characteristics, according to general size and finished tolerances. A fundamental machinability equation was experimentally tested on this project. Programs were written to optimize tool life. Another program was developed using the fundamental machinability equation. Based on analysis of current machining operations at Rock Island Arsenal, processing time was reduced from 10% to 33% for a variety of workpieces.

272 9358	High Power, Fast Switching, Silicon Controlled Rectifier	35
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Prior to this project, production techniques were nonexistent for high current (300 AMP), high voltage (1200 volt), 400 Hz, PNP silicon controlled rectifiers (thyristors) capable of operating at high switching speeds. Project achievements were demonstrated by a pilot line with a production rate of 20 units per 8-hour shift.

277 9808	Automatic In-Process Evaluation of Thick Film Printing and Hybrid Circuit Assembly	49
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It was demonstrated that an electro-optical system can be used for automatic quality control inspection of thick film networks for military hybrid microcircuits. The technique demonstrated that automatic inspection of substrates is feasible and has the potential to replace visual inspection of hybrid microcircuits with microscopes which is slow and fatiguing. This new technique can inspect hybrid substrates at a rate of 750 per hour and its efficiency allows for 100% inspection.

E80 3605

Transcalent High-Power Transistor

51

Semiconductor switches used in high current power conditioning equipment require large heat sinks with fins to conduct the heat away. This project developed specialized fixtures and procedures for rapid fabrication of heat pipes and for bonding the bases of two heat pipes to opposite sides of a silicon transistor wafer. High temperature brazing of the heat pipe body, sintering of porous wicks, and ceramic-to-metal sealing were production engineered to permit volume manufacture. Plating, lapping, and soldering methods were tailored to obtain blister-free, void-free metal joints between the heat pipes and the transistor wafer.

R79 3242

Digital Fault Isolation of
Printed Circuit Boards

56

The objective was to establish an automatic test and fault diagnostic system for complex digital PCBs containing microprocessors, RAMS, and ROMS. Goals were functional tested to 95% comprehension (ability to detect all faults) and fault isolation to the pin level of LSI devices or hybrid modules. The project results will be used for testing 218 different types digital PCBs in five military systems.

M77 6350
-2032Infrared Testing of Printed
Circuit Boards

80

This project produced an inspection system that uses infrared sensing and scanning techniques to locate PCB flaws such as poor solder joints, marginal components, electrical overloads, circuit imbalances, and neglected or improper heat sinking. This system produces a thermal map of the printed circuit board during normal operation and a comparison is made of the thermal characteristics of the board being tested with those of a prerecorded standard. The location of the faults are then read out by a computer.

R 78 3440

Production Testing of Control
Systems for Guided Weapons

84

This project produced a modular automatic test station with the capability to perform the following PPVT tests: shaft lock backlash, potentiometer null, shaft rotation and phasing, stall torque, angular rate, position gain; frequency response, step response, duration/duty cycle, shaft lock activation and cutter resistance. The use of the automated test station has reduced inspection time to 10 minutes per guided weapon.

180 7156

Ultrasonically Assisted
Machining for Superalloys

92

An ultrasonic lathe cutting system was designed and constructed. Ultrasonic cutting tests were conducted on 9310 low-carbon steel, 4340 medium-carbon steel, 17-4 PH stainless steel, ESR 4340 electroslag refined steel, three titanium-aluminum alloys, and refractalloy 26. It was concluded that ultrasonically assisted machining greatly improves the metal removal rates on high hardness steels.

R78 3167

Production Controls to Prevent
Plated Through Hole Cracking

148

The project's objective was to correlate optimum copper plating baths and multilayer board laminate material which would eliminate plated through hole (PTH) cracking. A formalized bath qualification procedure that significantly reduced PTH fractures was established.

COST REDUCTIONS

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
270 9297	MMT Measure for Mechanization of Ceramic Chip Capacitors	30

Processes mechanized included mixing, electrode screening, stacking, laminating, and sheet casting. Yield increases were attributed to better electrode registration from the screening and stacking machines and the improved material quality from the casting machine. Direct labor costs were reduced 17.5% and 33.5% for the two different capacitors that were used to prove out the system. Annual cost savings based on 1980 production quantities was estimated at \$2.7 million.

R79 3272	Flexible Printed Circuits With Integral Molded Connectors (FLEXICON)	59
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The project's objective was to establish high speed, low cost automated processes for terminating flexible printed wiring to connectors. Optimum processes and materials were selected for integration with an automated facility to produce 500 units per 8-hour shift. The cost advantage of the FLEXICON technique was estimated by comparing the present practice with that of a fully automated FLEXICON production facility.

573 6358	Investigation of Hot Parting Approach to Billet Separation	110
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The hot shear concept of billet separation involves heating steel billets, about 20-feet long, to forging temperature; hot shearing to mult length; followed by immediate transfer to the forging press; and forging into a projectile. A significant finding of this study was that, in terms of tolerance on length and weight and overall quality of the parted surface, hot sheared mults equaled or exceeded the results achieved using the band saw method of billet separation. Estimated cost savings were 34 and 51 cents each for the 105mm and 155mm projectiles, respectively.

679 7213	High Speed Chromium Plating Technique	133
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This project developed a new high-speed chromium plating process for gun tubes. Equipment and procedures were developed for plating chromium inside 1.2-meter sections of rifled and smooth bore gun tubes using a moving anode, high current density and high velocity solution flow. It was estimated that the application of this new process to the 155mm, M185 cannon tube would require only 3.3 hours processing time. Current production procedures require 9.5 hours.

575 1249	Advanced Technology for Pyrotechnic Mixtures and Munitions	<u>Page</u> 163
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This project improved the producibility of the AN-M8 and M18 grenades. It provided technical information which will improve the quality of the grenades, reduce production costs, and increase safety. The cost reductions associated with the AN-M8 amount to \$.082 per pound of HC mix produced. Cost reductions for the M18 grenade varied according to the color producing ingredients, but the cost savings ranged from \$.26 to \$.41 per grenade.

E79 3613	Vehicle Mounted Road Mine Detector System Antennas	191
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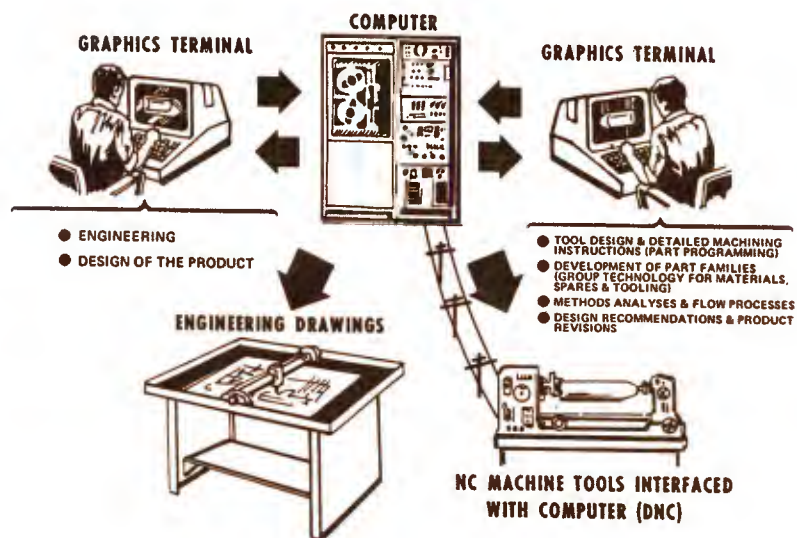
This project investigated production techniques for the antenna assembly module. It included an evaluation of metalworking, foaming, fiberglass, and plastic molding fabrication techniques. Manufacturing techniques and procedures were developed that reduced the cost of the antenna modules. The estimated cost using the developed method to fabricate antenna modules was \$95 as compared to the current unit cost of approximately \$350.

SAFETY

<u>Project Number</u>	<u>Project Title</u>	<u>Page</u>
578 4288	Explosive Safe Separation and Sensitivity Criteria	180

The project determined the safe spacing or shielding that was necessary to prevent propagation of an explosive chain. Some of the products that were the objects of this investigation included the 155mm, M483 projectile; flake TNT (168 pounds in a tote bin); 8-inch, M106 HE projectiles; and molten and solid TNT charges.

COMPUTER AIDED DESIGN/ COMPUTER AIDED MANUFACTURING (CAD/CAM)



INFORMATIONAL FLOW IN A COMPUTER SYSTEM

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 377 3169 titled, "Automatic Optical Inspection for Printed Circuit Boards and Components (CAD/CAM)" was completed in December 1980 at a cost of \$268,000.

BACKGROUND

Inspection cost of several major missiles systems (e.g. Hell Fire, Pershing II, Sam-D and Sprint) have soared during the production phase due to the time consuming task of inspecting printed circuit board (PCB) assemblies. At present, the government and industry normally inspect these assemblies visually. This has proven to be very tedious, inefficient, and costly when the production quantities are extremely large. To solve this problem, a reliable low cost automated inspection system is needed to detect common defects such as: excess solder, lack of solder, solder bridges, improper lead cutting and bending, and missing or incorrectly oriented parts.

Various commercial companies have demonstrated their ability in the area of optical scan comparator equipment. However, the developed techniques have not been applied towards inspecting PCB or microcircuits.

SUMMARY

The major objective of this project was to improve the system of inspecting printed wiring boards. To achieve this goal advancements were needed in the area of methods and equipment development. As a secondary objective, these improvements when implemented should eliminate the human element as much as possible, thus improving product quality and lowering cost.

Two approaches were taken by different companies to achieve the objectives. One approach was to employ a close-circuit television system, while the second approach was the application of a high speed laser scanning system in examining boards. As the project progressed, the first approach was completed and proven to be feasible; however, it was impractical for industrial application and needed additional development. The second approach, now in its final stages, was adopted for further development because it had demonstrated high adaptability to function in a large volume production environment. The second approach had progressed to the point where tasks such as solder bridges and component lead direction could be detected accurately. At the completion of this project a production laser scanner prototype, Figure 1, was completed and ready for implementation into the manufacturing facility.

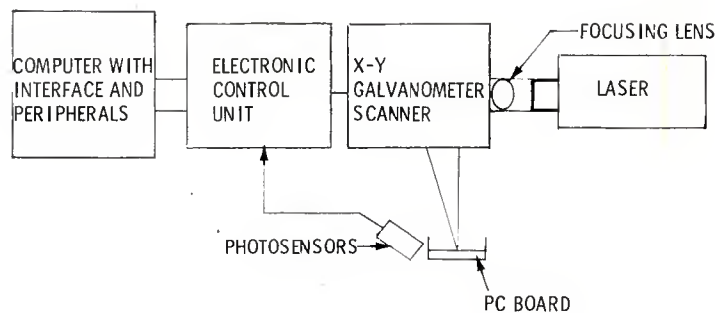


Figure 1 - Production Laser Scanner Prototype

BENEFITS

The prototype laser scanner has the capability of inspecting boards for the majority of defects commonly encountered in PCB manufacturing. With the development of this system, the expected net savings in rework could meet or exceed 80% of the total rework cost of \$1,890,000 per year (cost figure based on past rework data of approximately 84,000 boards requiring rework). To date, cost information is being accumulated to substantiate this prediction.

IMPLEMENTATION

The prototype system is presently on line at the Chrysler Huntsville Electronic Division. This system is commercially available from Chrysler.

MORE INFORMATION

For additional information consult the final technical report titled, "A Laser Scanner for Evaluation of Circuit Boards." Detailed information may be obtained from Mr. Robert L. Brown, MICOM, AV 746-5742 or Commercial (205) 876-5742. For information concerning detailed implementation refer to project R80 3169.

Summary Report was prepared by T. Locke, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 573 4500 titled, "Modernized Testing Technology Providing for Immediate Data Acquisition, Reduction, and Dissemination, CAM Related," was completed by the US Army Armament Command in August 1974 at a cost of \$425,000.

BACKGROUND

Prior to this effort, instrumentation for ballistic testing of nuclear munitions consisted of fitting telemetry units to samples of each production quantity. The variables data (analog signals) obtained were recorded on oscillograph recorders. Analysis of these paper traces was time consuming, error prone, and required a highly skilled professional. Analysis of radar coverage of conventional ammunition was similarly constrained. This effort was undertaken to reduce costs and improve the timeliness and reliability of the analysis of ballistic test data. There were no prior efforts.

SUMMARY

The objective of this effort was to reduce the cost and delays associated with reduction and analysis of test data. The approach was to design and develop digital computer systems with data acquisition and data reduction capabilities. A system was designed which transmitted analog data to a central site for processing. Equipment was fabricated, and a limited operational capability was developed.

The successful results of this effort significantly influenced the system design of the Data Acquisition Support System (DASS), illustrated in Figure 1.

A Scientific Control Corp model 4700 computer was the control process computer. A bandwidth capability able to receive better than 500,000 samples per second of incoming data with an ability to simultaneously transfer 500,000 samples per second of data to external devices was available. A memory capability consisted of 32,000 words (16 bits wide) of data with the option to expand to 64,000 words via a memory map. The computer stored data on a fixed head magnetic disc for rapid storage and transfer of data. A movable head disc was used for storage of programs and/or intermediate results.

A specialized buffer or front end provided for the acquisition and conversion of raw analog data and specially encoded digital data into a digitized format, which was then digital-computer compatible. Pressure-time data was acquired, transmitted and reduced. Graphic and alpha-numeric information on the pressure-time data was displayed at the test location within 10 seconds of the test action.

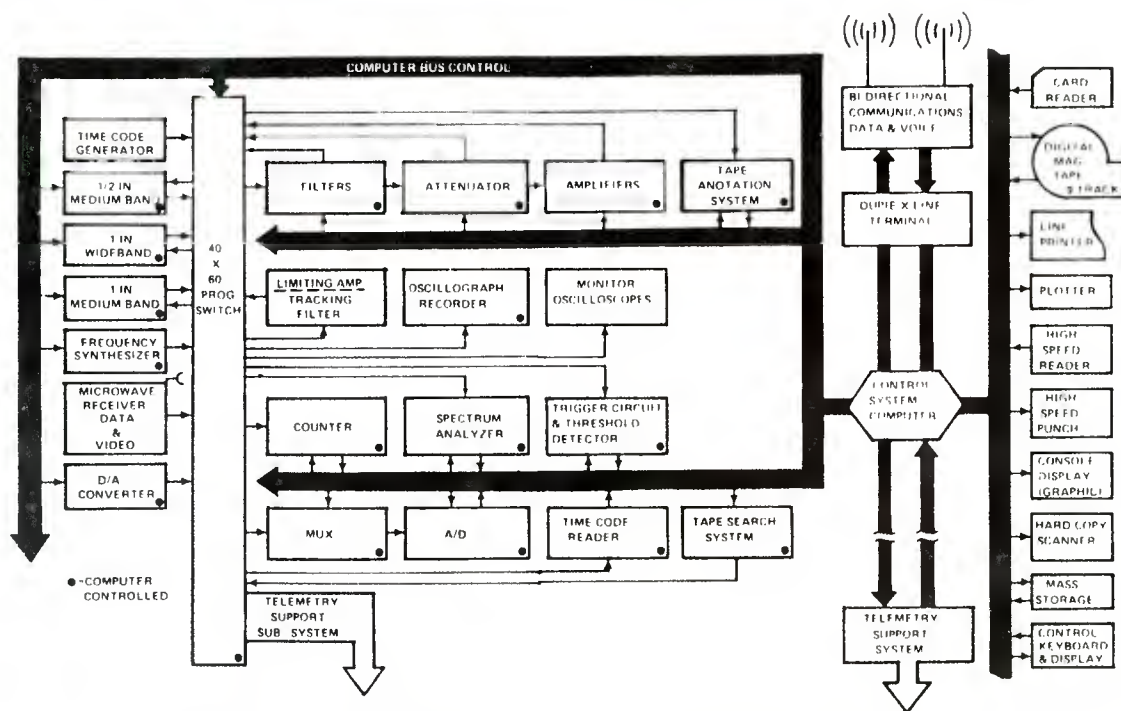


Figure 1 - Flowchart of Data Acquisition Support System

BENEFITS

On-site analysis of limited types of test data was now possible. Improvements have been implemented in field test procedures and planned equipment redundancy has been reduced.

IMPLEMENTATION

The technological advance made from the project was not only in the area of the speed of data reduction. A chain reaction was initiated, which has led to improvements in testing procedures, data logging and data storage.

The results of this project were applied to Manufacturing Methods and Technology project 574 4500, with the same title as project 573 4500.

ADDITIONAL INFORMATION

Additional information can be obtained in a technical report titled, "Computer Aided Testing Technology and Signal Processing," December 1980; the Defense Technical Information Center number for this report is ADB 053296.

The project officer is Mr. Leonard Goldsmith, US Army Armament Research and Development Command, AV 880-3357 or Commercial (201) 328-4955.

Summary Report was prepared by Stephen A. McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 673 7248, 674 7248 and 675 7248 titled, "Improved Manufacturing Control Through Data Automation (CAM Related)", were completed by the US Army Armament Material Readiness Command in June 1979 at a total cost of \$396,000.

BACKGROUND

At Watervliet Arsenal, the Production Control Activities exercise coordination of production facilities to produce cannons on schedule and at optimum cost. While Watervliet Arsenal continues as the leader in cannon manufacturing technology, the development of advanced production control systems has not kept pace with advancements in manufacturing technology. The manual production control systems were not sufficiently responsive to the constantly changing workload environment to permit optimization of high productivity and economics offered by modern manufacturing methods and equipment. The manual system was slow. Management and financial reports were being provided up to three days after work was performed. The manual reporting system weaknesses were concentrated in the areas of labor reporting. Planning, forecasting, scheduling, material control and machine loading were very difficult and very time consuming to perform under this manual system. The problem required modernization of Production Control Systems using data automation techniques in order to realize the full economic benefits of modern manufacturing technology.

SUMMARY

The objective of these projects was to establish a Production Automated Control System (PACS) to facilitate planning, workload forecasting, short and long range scheduling, material control and machine loading. The primary objective was to collect, process and feed back to users all production data within a 24-hour period; to reduce planning and production lead times and to increase productivity and utilization of resources.

The projects completed a feasibility study and then developed, installed and implemented an automated shop data collection (SDC) at Watervliet Arsenal. All production reporting by shop labor is accomplished through the system (see Figure 1). In addition, a workload forecasting system which operated in a real-time mode to permit on-line simulations, was established along with a common computer data base for bill of materials and production routing.

Computer master files have been established for the Production Planning and Control Data Base. The files are SDC Master Employee, Component Master, Product Structure, and On-Line-Real-Time Master Routing (using a Cathode Ray Tube (CRT) terminal for maintenance of file).

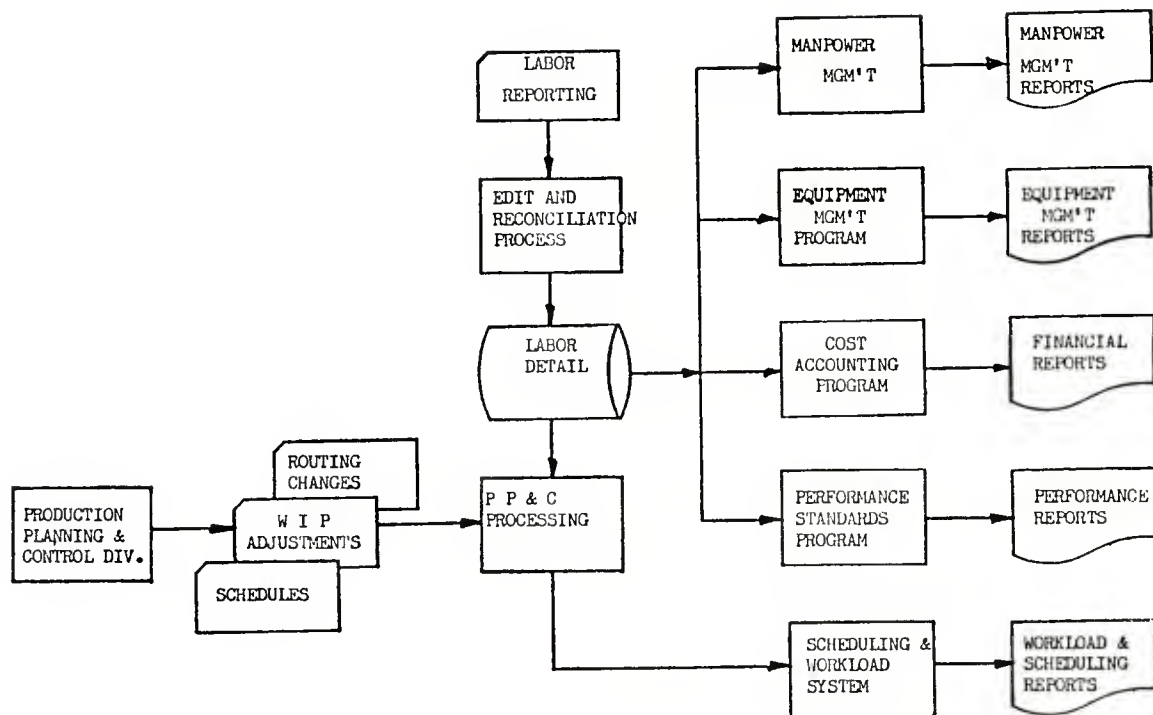


Figure 1 - Labor Reporting Interface

A "labor control and distribution" system for the operations directorate was installed and is operational. All labor transactions are processed daily through the 42 SDC terminals.

The data base master files are used for computer generated: Cost Estimating, Cost Accounting, Labor and Workload Forecasting, Production Scheduling, Machine Loading, Bills of Material Processing, Automatic Generation of the Procurement Request for Production Material and Associated Stores Issue Tickets.

A substantial degree of data automation has been integrated with the financial management area as well as the Production Planning and Control area. The use of common data base files has eliminated organizations maintaining their own, sometimes inconsistent, duplicate files.

BENEFITS

The SDC system has increased productivity by providing more accurate and timely reports to shop managers. Feedback of data to shop managers has reduced turn-around time of information from three days to one day. Estimated yearly savings of \$176,000 will be obtained from the elimination of eight time control personnel, elimination of an outside vendor keypunch contract, and from the increase in shop efficiencies of an estimated one percent attributable to this project.

IMPLEMENTATION

Project implementation was achieved at Watervliet Arsenal over the life of this project.

MORE INFORMATION

Additional information may be obtained by contacting Mr. D. R. Ippolito, SARWV-ODP-S, Arsenal AV 974-5719 or Commercial (518) 266-4610, Ext. 5719. A technical report has been prepared and is available from Watervliet Arsenal.

Summary Report was prepared by Al Adlfinger, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 677 7707 titled, "Automated Process Control for Machining (CAM)," was completed by the US Army Armament Materiel Readiness Command in December 1979 at a cost of \$105,000.

BACKGROUND

Metal cutting conditions (speeds, feeds, tool geometry, etc.) are selected based on empirical data or general handbook recommendations. The present selection process does not provide adequate guidance for workpiece variability combinations in feed and depth of cut, combinations of tool shape and cutting speed. This project was undertaken to develop a computer-aided system for the selection of metal cutting conditions.

As a result of prior efforts, three computer programs were developed and tested. A machining performance index program, a production optimization (PIM) program, and a machining optimization (MACHOP) program were documented in technical reports. The Defense Technical Information Center (DTIC) reference numbers are ADA 754569 and ADA 018124.

SUMMARY

The objective of this project was to establish a computerized metal cutting matrix for machining operations and workpiece characteristics, according to general size and finished tolerances. A fundamental machinability equation was developed under independent efforts and experimentally tested on this project. In simple form, the equation is: $Vx = \frac{A \cdot B}{q}$ where V is the cutting speed, x is the tool life, B is the work material constant, q is the size of cut constant and A is the tool and environment constant.

Programs were written to optimize tool life. The tool life in this project is defined as the number of minutes of cutting time required for a specific flank wear. A computer program was also developed using the fundamental machinability equation. This program enables the selection of the optimum feed and speed from the options on a given machine tool. This program was written in Fortran and portions of the program were also programmed for a hand held programmable calculator (Hewlett Packard 67). The optimum speed and feed is the combination that results in the minimum machining cost. This optimization is done by constructing a matrix, or tabulation, Table 1, of the unit cost (cost per operation) for each of the suitable combinations of feed and speed.

Table 1 - Unit Costs Based on the Machinability Equation

<u>Speed</u> <u>RPM</u>	<u>Feed</u> <u>ipr</u>	<u>Tool</u> <u>Life</u>	<u>Cutting</u> <u>Time</u>	<u>Tool</u> <u>Change</u> <u>Time</u>	<u>Hand-</u> <u>ling</u> <u>Time</u>	<u>Total</u> <u>Time</u>	<u>Labor</u>	<u>Cost</u> <u>Tool</u>	<u>Total</u>
255	.0168	15	11.09	0.74	11	22.83	6.85	.31	7.16
255	.0210	7.8	8.87	1.15	11	21.02	6.31	.48	6.79
255	.0259	3.8	7.19	1.89	11	20.08	6.02	.79	6.81
220	.0337	3.4	6.40	1.89	11	19.29	5.79	.79	6.58

Experimental data were collected under controlled laboratory conditions. All tests were conducted on a numerically controlled lathe with a variable speed drive motor. Tool materials were 3/8" square, high-speed steel, and 1/8" thick carbide triangular throwaway inserts. The work material was 4140 steel at two hardness levels. Tool wear and workpiece surface finish was monitored during the machining tests. A computer program was developed to predict surface finish based on tool shape, feed, and speed.

Guidelines were identified for selecting the optimum cutting conditions:

1. Select the best tool and shape.
2. Take as deep a cut as required. That is, one deep cut is better than two light ones.
3. Use as large a feed as possible, consistent with surface finish and rigidity.
4. Select the cutting speed that results in the optimum tool life based on analysis with computer program.

The experimental data were used to refine the constants used in the basic formula. The guidelines were used in the sequence listed to aid in reliable data collection. A method for the selection of metal cutting conditions in a turning operation was developed.

Several production parts were analyzed in terms of time and cost of cutting using the results from this project. Based on this analysis, several recommendations were made for changes to actual production machining conditions.

The system is designed to aid process planners, NC programmers, methods and standards analysts, estimators, tool engineers and production supervisors. The system also provides data applicable in production scheduling and quality control.

BENEFITS

Based on analysis of current machining operations at Rock Island Arsenal, savings estimates have ranged from 10% to 33% in time, and from \$3.00 to \$5.00 in cost for the processing of each workpiece.

Additional efforts have been planned to demonstrate this system for turning operations at Rock Island Arsenal. Also, efforts have been planned to develop an equivalent system for milling and drilling.

IMPLEMENTATION

The system for turning is planned to be implemented at Rock Island Arsenal. Implementation beyond Rock Island Arsenal will be made by distribution of the technical report and computer programs.

MORE INFORMATION

Additional information concerning the project results may be obtained from Mr. Ray Kirschbaum, SARRI-ENM, Rock Island Arsenal, Rock Island, IL 61299, AV 793-5363 or Commercial (309) 794-5363.

Reference technical report DTIC #ADA 088416 titled, "Automated Process Control for Machining (CAM)," December 1979. Author is Joseph Datsko, University of Michigan.

Summary Report was prepared by Steve McGlone, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects A74 201N and 776 8036 titled, "Numerically Controlled Helmet Die Sinking," were completed by the US Army Natick Research and Development Command in September 1980 at costs of \$62,800 and \$75,000, respectively.

BACKGROUND

The Natick Research and Development Command (NARADCOM) is responsible for the development of advanced Army equipment and supplies such as protective clothing, field support equipment, etc. In an effort to provide improved uniformity and interchangeability, NARADCOM investigated the use of numerical controlled equipment.

Body armor such as bullet proof vests and helmets require complex surfaces to fit the human anatomy. The production of tools, molds, and dies incorporating these complex surfaces require precision machining. The present system of surface definition, i.e., engineering specifications for helmets and helmet liners allow various manufacturers to produce helmets and liners according to their own drawing interpretation. The lack of a sufficient number of cross-section profile curves necessitates that modeling techniques and interpolating be used to complete the surface between profile curves. Since different modeling techniques are used by different manufacturers, variances in surface definition exist. This leads to poor fit and interchangeability problems.

SUMMARY

The purpose of this project was to prove the feasibility of using numerical control techniques as an aid to the competitive procurement of material having complex sculptured surfaces. The program involved (1) the development of a computerized sculptured surface tool manufacturing system for the combat helmet and liner and (2) the manufacture of mold sets for the helmet and liner on NC equipment.

The first phase of the program was conducted by the Army Management and Engineering Training Agency (AMETA). AMETA determined no software was available in the public domain that could adequately cut a helmet contour. Their effort revealed that it was not feasible to provide numerical control programs for fabrication of complex sculptured surfaces for competitive procurement. NC machining of helmet contours would require proprietary systems. Since various manufacturers utilize different NC systems, the unique NC programs could not be Government furnished material (GFM) in competitive procurements.

Picatinny Arsenal conducted the second phase of the program. Their objective was to fabricate a helmet mold using a 4-axis machining center. The FMILL computer program was used to develop surfaces, and Control Data Corporation's APT and APTLEFT were

used for the generation of NC programs. A helmet mold was successfully fabricated on a Kearny & Trecker Model II, four-axis machining center.

BENEFITS

This program proved the feasibility of producing a helmet mold using NC technology. However, the computer programs developed would not lend themselves for distribution for competitive procurement since they are only suitable for the type of machine they were developed for.

IMPLEMENTATION

NARADCOM has continued to investigate the feasibility of non-proprietary software. Several companies have expressed an interest in developing such programs. NARADCOM intends to introduce NC technology into its programs as the opportunity presents itself and funds are made available.

MORE INFORMATION

Additional information is available from Mr. Abraham L. Lastnik, NARADCOM, AUTOVON 955-2461 or Commercial (617) 653-1000 Ext. 2461.

Summary Report was prepared by J. H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology project Q76 8035 titled, "Automated Production of Insulated Footwear," was completed by the US Army Natick Research and Development Command in September 1980 at a cost of \$390,000.

BACKGROUND

The insulated boot currently used by the Armed Services is fabricated by techniques which are becoming obsolete in the footwear industry. Fabrication involves many hand operations and consists of the hand layup of 44 component pieces over a footwear last. The various parts are formed into a unit through the use of adhesives. The resultant boot is functionally adequate but suffers from the drawback of excessive weight and a rapid loss of insulating properties when the outer protective layer is torn or punctured.

An expanded improved polyurethane pull-on type insulated boot, Figure 1, consisting of five component parts has been developed. This new insulated boot is lighter than standard insulated boots and insulating properties are not affected when punctured. Experimental boots have been produced on manually operated pilot plant equipment. However, there is no known industrial capability for mass production in accordance with present design and physical property requirements. Under a prior project, production equipment requirements and processes were determined.

SUMMARY

The objective of this project was to set up and demonstrate a manufacturing line capable of continuous production of insulated boots from liquid injection molded expanded polyurethane. A manufacturing line has been designed, fabricated, and installed to produce the finished footwear. The equipment is capable of producing boots at a minimum production rate of sixty pairs of boots per week; running one shift per day, five days per week. The equipment is capable of producing boots in a size range of 4 through 14 and widths XN to XW.



Figure 1 -

Polyurethane Insulated
Boots

The production method being used consists of molding a fabric lined, urethane foam upper utilizing four individual mold unit stations and a three-stream foam injection unit. The uppers are trimmed, buffed, and sprayed in specific areas with a release coat. A fabric tube sock is then slipped over the foam upper. The uppers are "banked" until sufficient quantities are produced to warrant switching the equipment to the outsole producing cycle. During this operation, using the same mold stations, the upper is relasted and the outsole is then molded to the upper using a two-stream system in the foam injection unit. After curing, the boot is stripped, trimmed, and buffed.

At this point, the boot is ready for application of the outer skin coating. An electrostatic spray unit is used to coat the boots with a tough urethane film. The basic principle is to pump two components to a spinning disc, mixing the components just prior to depositing in a well located in the center of the disc. The disc can be programmed to raise and lower in order to deposit the coating where desired from top to bottom of the boot. The spinning disc "sprays" the coating toward the rotating boot and the urethane particles are electrostatically attracted to the boot. After coating, the boot is cured and then trimmed at the top edge and the snow collar attached.

BENEFITS

This MMT program successfully developed the manufacturing technology and quality assurance information for producing insulated footwear on an automotive production line.

IMPLEMENTATION

The manufacturing technology for this new method of fabricating insulated footwear is available. A feasibility test of the Lightweight Insulated Boot was conducted by the Cold Regions Test Center from November 1979 to March 1980. Boots were evaluated against 11 criteria. Although 8 were met and 2 were partially met, one deficiency was identified. It is uncertain at this point in time if the lightweight polyurethane boot will be typed classified.

MORE INFORMATION

The final report, Technical Report NATICK TR-80/019, titled, "Production of Insulated Footwear Using Injection Molding Equipment," dated September 1980, describes in detail all production equipment, production methods, and process conditions required to fabricate the lightweight insulated boot. Contact Dr. Roy Laible, NARADCOM, AV 955-2392 or Commercial (617) 653-1000, Ext. 2392.

Summary Report was prepared by J. H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project T79 5082 titled, "Flexible Machining Systems (FMS Pilot Line for TCV Components (Phase I)," was completed by the US Army Tank Automotive Command in January 1981 at a cost of \$440,000.

BACKGROUND

The economics of scale achievable in mass production industries are usually substantial. In machining, for example, the unit cost of mass-produced items is commonly one percent of the unit cost of the same item produced at low volumes. Mass machining operations make extensive use of highly automated integrated systems which are dedicated to individual parts. Because the machines are dedicated, large quantities of parts are needed to amortize the large capital investments required.

Parts for tracked combat vehicles are typically not manufactured in large quantities due to limited requirements. Thus, mass production technologies are not being utilized.

SUMMARY

The advantages of mass production can be realized in producing medium quantity size lots by applying a concept known as Flexible Machining System (FMS). The objectives of the Army's FMS Program are to enhance FMS technology and solve selected technological problems that are currently limiting the application of the concept. One goal of the program is to see six to eight machining systems operating in the Army contractor community.

The entire FMS Program is a multi-year, multi-phase undertaking. The program has four tasks including: Task I - System Configuration and Evaluation, Task II - Simulation Development, Task III - Hardware Evaluation and System Architecture, and Task IV - Software Architecture. Each phase of the program will deal with each of these tasks.

The objective of the first phase (project T79 5082) is to determine the relative advantages of a FMS versus conventional manufacturing techniques.

BENEFITS

This project has laid the ground work for carrying out the Army's entire FMS Program and has led to an awareness of the potential for using FMS. Tangible benefits will not materialize until additional program progress is made.

IMPLEMENTATION

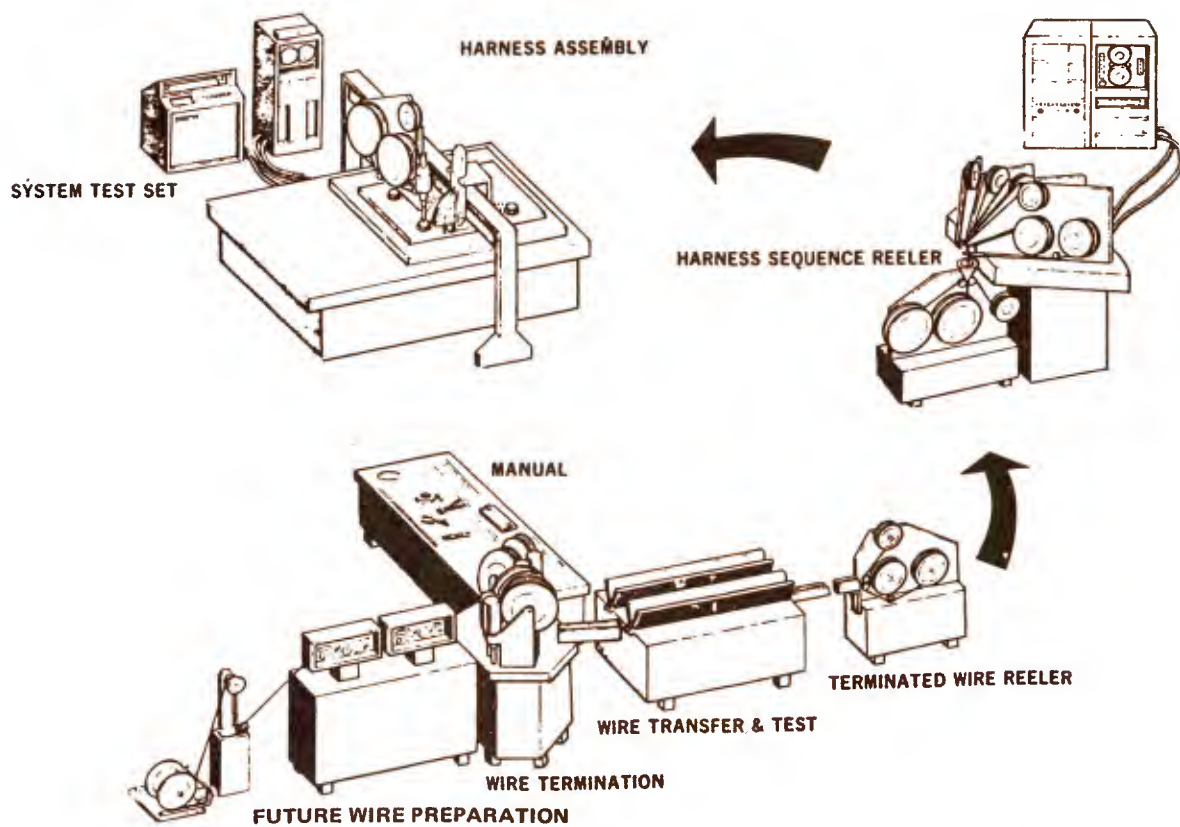
Since the FMS Program is in its infancy stages, actual hardware facilitization is not planned. However, as a result of this project, Rock Island Arsenal is currently considering the feasibility of establishing a FMS.

MORE INFORMATION

Additional information and a copy of the final report R-1391 titled, "Flexible Machining System, Final Progress Report for Period 1 April 1979 to 31 December 1979," dated June 1980 is available from Mr. Sam Goodman, US Army Tank Automotive Command, AV 273-1814 or Commercial (313) 573-1814.

Summary Report was prepared by J. H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

ELECTRONICS



CONCEPTUAL APPROACH TO FIXING
ELECTRICAL CONNECTORS TO CABLES

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 270 9217 titled, "Ferrite Solid State Limiter Protector," was completed by the US Army Electronics R&D Command in June 1978 at a cost of \$99,000.

BACKGROUND

The Ferrite Solid State Limiter Protector is a device developed for radar receiver front end amplifier protection at X and Ku-band frequencies. Amplifier damage is caused by the high energy transmitter turn-on pulse (feedback) when switching the antenna from transmitter to receiver. The protector is designed for a minimum of 10,000 hours of operation and would replace the TR 6560 tube (200 hour life rating) and the TR 8787 tube (500 hour life rating). Low cost production techniques were needed to replace manual fabrication and testing methods.

SUMMARY

Varian Associates at Beverly, MA, established the manufacturing processes, jigs, fixtures and production test procedures for the X-Band Ferrite-Limiter, designated VFX-9500. The device, Figure 1, consists of three major subassemblies: a Pre-TR section, a Ferrite Rod section, and a Diode Limiter section. The VFX-9500 provides an improved high power overload performance by utilizing a gas filled, quartz cylinder type, Pre-TR input section. In normal operation, the Pre-TR does not react and all limiting is done by the Ferrite-Diode sections. The Pre-TR, Chlorine, Argon gas chamber becomes completely ionized between four and five KW. The Ferrite-Diode Limiter is then subjected to the Pre-TR leakage rather than the full incident power.

Tasks included: epoxy bonding ferrite rods to the waveguide wall; epoxy potting the Alnico-5 permanent magnet; baking; acid cleaning; copper, silver and cadmium plating and irriditing.

Each Pre-TR gas cylinder was tested after removal from the pump station to assure correct firing level. Ferrite and Diode Limiter sections were subjected to three temperature cycles and the Ferrite-Rod was also exposed to an additional bench drop test before final assembly. The Ferrite section magnetic field was adjusted by sweeping across the full frequency band. Diode-Limiter video current was set for breakdown power at 9.3 GHz and tested at midband. Final VFX-9500 electrical tests consisted of insertion loss, VSWR, firing power, recovery time, flat leakage power, spike amplitude, spike energy and phase linearity.

Significant achievement was a VFX-9500 recovery time of 0.1 micro-second compared to typical 0.5 microsecond values for non-solid state devices. Twenty-two VFX-9500 devices were successfully built and a production rate of 10 units per month was demonstrated.

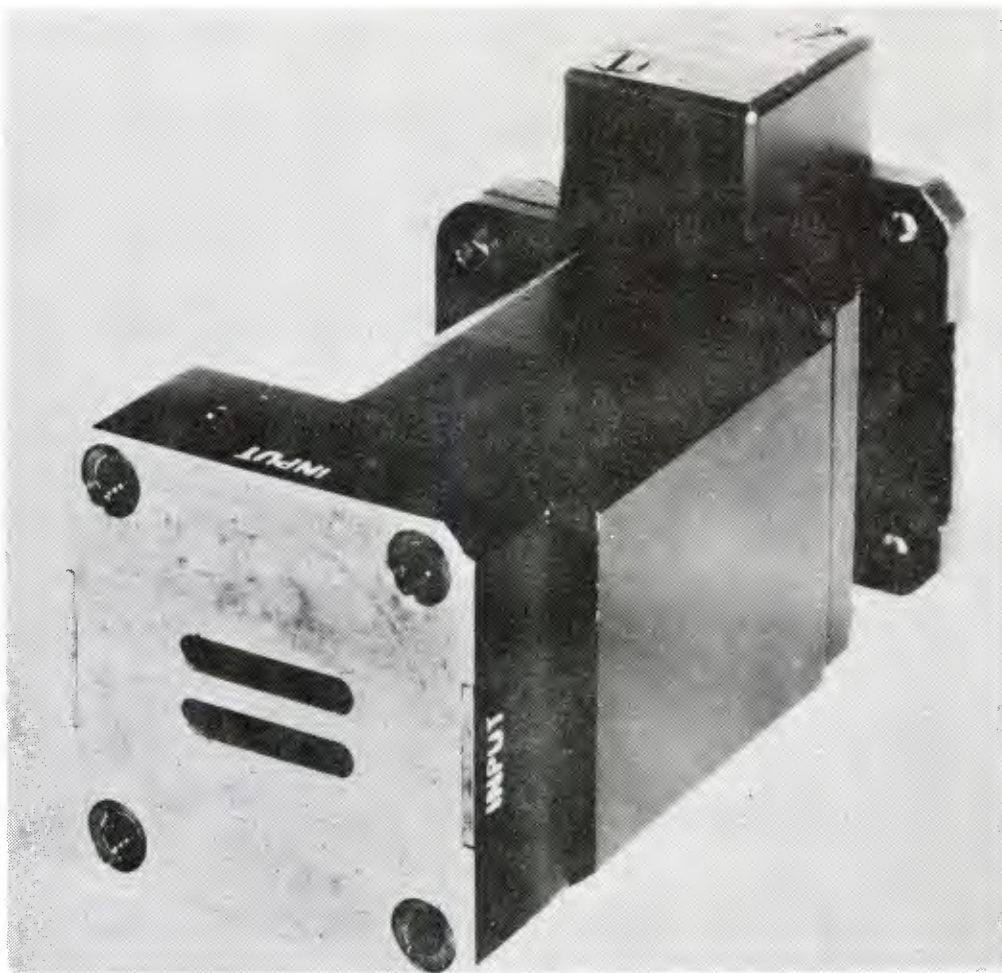


Figure 1 - VFX-9500 - Ferrite Solid State Limiter Protector

BENEFITS

This effort established a manufacturing capability for a ferrite solid state receiver protector. Prior to this project, a solid state limiter protector was not commercially available.

IMPLEMENTATION

Due to changes in temperature requirements for the AN/TPQ-36, the VFX-9500 was not implemented. However, many techniques established for the VFX-9500 were used by Varian to fabricate a higher temperature rated solid state limiter, now incorporated in the AN/TPQ-36.

MORE INFORMATION

Additional information may be obtained from Mr. Samuel Dixon, ERADCOM, Ft. Monmouth, NJ, AV 995-4983 or Commercial (201) 544-4983.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 270 9297 titled, "MMT Measure for Mechanization of Ceramic Chip Capacitors," was completed by the US Army Electronics Command in June 1974 at a cost of \$133,000.

BACKGROUND

Monolithic ceramic chip capacitors are commonly used in thick or thin film circuits as coupling or bypass capacitors where extreme component stability is not required. These devices consist of many layers of thin film (.0025 inch thick), high dielectric material with alternate layers of metallic electrodes. The dielectric material is basically barium titanate; the electroding material is an alloy of platinum, palladium and gold; and the end termination is composed of silver and glass frit. See Figure 1. At the time of contract award, chip fabrication methods were slow and laborious. New techniques were needed to increase capacitor chip volume production methods while maintaining their reliability.

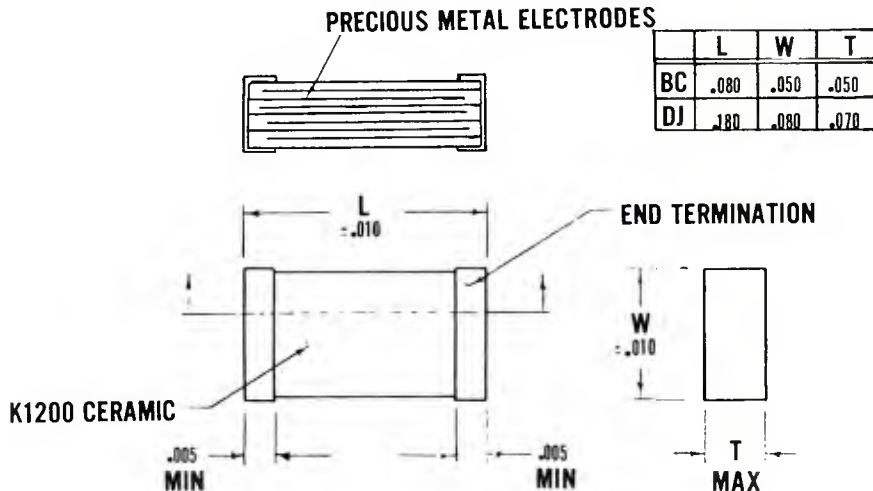


Figure 1 -

Monolithic Ceramic Chip Capacitor

SUMMARY

The project's objective was to establish optimum manufacturing processes for small ceramic chip capacitors. Work was performed by CENTRALAB, ELECTRONICS DIVISION, GLOBE UNION, INC., and consisted of powder blending and milling; sheet casting, printing, and screening; stacking, blanking and laminating; and automatic cutting, tumbling and testing. Two basic chips rated 50 volts with capacitance values 0.01 Mfd and 0.1 Mfd ± 10 and the respective BC and DJ dimensions given in Figure 1 were chosen to demonstrate the technology in separate 50,000 unit pilot runs. The capacitors were to meet the requirements of MIL-C-55861A with a maximum .001% failure rate per 1000 hours at a 90% confidence level.

Defects and voids in the ceramic greenware such as moisture and foreign particles were eliminated by pressurizing the material with dry nitrogen rather than air, and filtering the ceramic slip before casting. Polyethylene coated paper was selected as the material which most satisfactorily solved the problems of flatness, material compatibility and strength.

Processes mechanized included mixing, electrode screening, stacking, laminating and sheet casting. Yield increases were attributed to better electrode registration from the screening and stacking machines and the improved material quality from the casting machine. A maximum production rate of 25,000 units per hour was achieved for both capacitor chips.

Three thousand, six-hundred chip capacitors of both types were randomly selected from the pilot run and given a 4000-hour life test per MIL-C-55681A. A prescreen 100-hour burn-in was followed by capacitance, dissipation factor and insulation resistance measurements at 125°C. These values were used as the initial readings for the 4000-hour life test.

Tests indicated one, 0.01 Mfd. and ninety-eight, 0.1 Mfd. capacitors failed due to low insulation resistance. Investigation determined the 0.01 Mfd. capacitor failure was the result of improper installation. No 0.01 Mfd. capacitor failures for 4000-hours equated to a 0.002% failure rate per 1000-hours at the 90% confidence level.

The ninety-eight, 0.1 Mfd. capacitor failures proved to be the result of a displaced electrode. This may have been due to a manufacturing error. A review of the pilot run showed that the stacking machine was stopped in mid-operation several times which allowed the material to creep forward by as much as .015 inches, misregistering the electrode. An overdrive motor was installed on the unwind section of the machine to insure that when stopped, the material would not move forward. This correction was verified by making a 10,000 piece evaluation run. In no case were the electrodes found misregistered. A failure rate calculation was not performed due to the high number of observed failures.

BENEFITS

As a result of this project, direct labor costs were reduced 17.5% for the 0.01 Mfd. capacitor and 33.5% for the 0.1 Mfd. capacitor. Production samples showed the

ability to improve yields between 12% and 17%. In terms of 1974 dollars, the annual cost savings based on 1980 production quantities is approximately \$2.7 million.

IMPLEMENTATION

Processes developed by this effort were implemented in 1974 in the Centralab Ceramic Capacitor Chip Manufacturing Plant at Los Angeles, California, and are still in use. Design and construction cost of the casting machine was borne by the contractor and this equipment was placed in operation at the above location.

MORE INFORMATION

Additional details may be obtained from Mr. Rupe Jarboe, Centralab, Inc., El Paso, Texas. Phone (915) 779-3961. The contract was DAAB05-71-C-2633.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 270 9300 titled, "MM&T Measure for Beam-Lead Devices," was terminated by the US Army Electronics Command in June 1975 after expending \$193,000.

BACKGROUND

At the time of contract award, Integrated Helicopter Avionics System (IHAS) and Cheyenne helicopter, Microelectronic Modular Assemblies (MEMAs) used IC chips with aluminum metallization and aluminum bonding pads for internal and external electrical connections. The chips were soldered to the MEMA substrate and electrically connected by bonding 1 mil aluminum wire between each chip pad and appropriate substrate wiring point. The project's goal was to substitute Beam-Lead ICs for standard MEMA chip and wire technology.

SUMMARY

The MEMA contract was awarded to Teledyne Systems who subcontracted the Beam-Lead task to the Motorola Semiconductor Group, Phoenix, Arizona. Motorola's objective was to establish production processes for beam leads on silicon utilizing bipolar, TTL, 5400 series, logic. These circuits were designed to be interchangeable replacements for four MEMAs: the Even Stage Vertical Register (ESVR), Odd Stage Vertical Register (OSVR), UP/DOWN Counter (UDC) and Memory Information Register (MIR) used in the Cheyenne helicopter computer system.

One Medium Scale Integrated (MSI) master chip Beam-Lead die, consisting of approximately 50 gates and a 122 square mil area, was used for all the above circuits. The master chip had two layers of titanium-platinum-gold metallization separated by a layer of chemically vapor-deposited silicon dioxide (SiO_2). Contact holes, or vias, etched in the intermediate dielectric SiO_2 layer allowed the two metal layers to be connected electrically. See Figure 1.

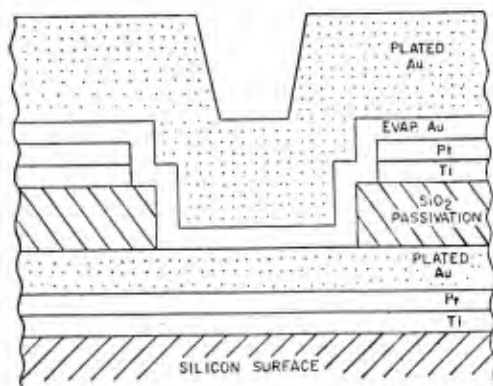


Figure 1 -
Original Metal System

Twenty-four gold plated beams, an integral part of the chip metallization, furnished both mechanical support and electrical connection.

The completed dice reached the final electrical probing station but failed because the diffusion parameters changed during the intermediate glass dielectric application. An in-depth evaluation of the existing technology and a proposed metallization system modification determined that project continuation was unwarranted for the present.

BENEFITS

No direct benefits can be imputed to the project since the Beam-lead devices were not successfully fabricated. Projects 274 9753 and 275 9753 were written to expand the technology in Beam-Lead ICs initiated by this contract.

IMPLEMENTATION

Because of failure to achieve stated objectives, this MMT project was not directly implemented.

MORE INFORMATION

Additional information may be obtained from Mr. James Kelly, CORADCOM, Ft. Monmouth, NJ, AV 992-2682 or Commercial (201) 532-2682. The contract was DAAB05-71-C2624.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 272 9358 titled, "MM&T High Power, Fast Switching, Silicon Controlled Rectifier," was completed by the US Army Electronics Command in January 1975 at a cost of \$220,000.

BACKGROUND

Prior to this project, production techniques were nonexistent for high current (300 AMP), high voltage (1200 volt), 400 Hz, PNP silicon controlled rectifiers (thyristors) capable of operating at high switching speeds. The silicon controlled rectifier (SCR) type was originally developed and shown feasible in R&D. It employs a beam fired integrated gate drive design, all diffused junctions and a total pressure contact encapsulated package.

Manufacturing tolerances and process controls were needed so that a uniform product could be economically produced outside the laboratory.

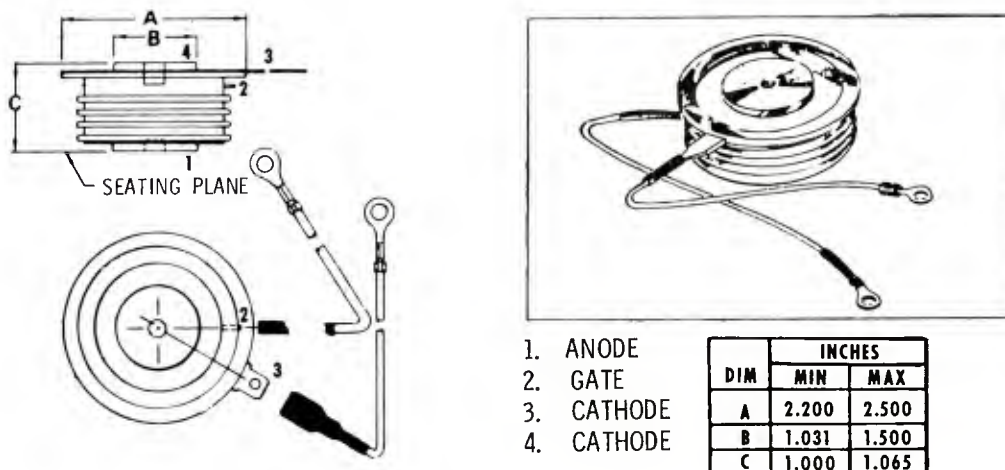


Figure 1 - Semiconductor Device, Thyristor Type

SUMMARY

The contract's objective was to establish a production capability for the High Power Fast Switching Thyristor shown in Figure 1. Motorola, Inc., fabricated a thyristor with a 13.5 mil thick silicon wafer which was selected to have a starting resistivity between 55 and 72 ohm-cm. Figure 2 is a cross section of the thyristor which shows this silicon wafer.

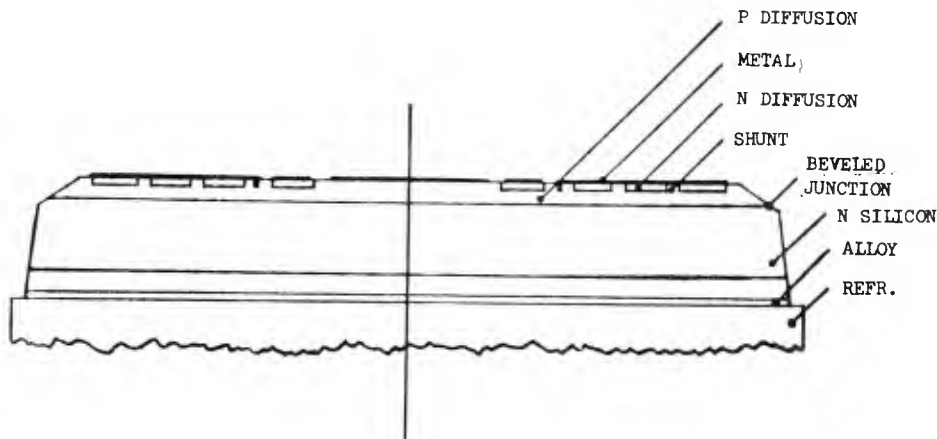


Figure 2 - Cross Section of High Frequency Thyristor Showing Silicon Wafer

Wafer processing tasks included gallium, phosphorous, and gold diffusion, photoresist masking, chemical etching, aluminum metallization, and glass passivation and curing. Precise control of the furnace diffusion temperature and operating parameters of the various processes was demonstrated.

Wafer structural support was provided by a matched coefficient refractory tungsten metal disc which was bonded to the silicon by a high temperature alloying technique. Thyristor switching speed was achieved by thermal diffusion of gold, and the junctions were delineated by mechanical abrasion and chemical etching.

Wafer electrical test consisted of DC blocking voltage both forward and reverse, gate voltage and current, and turnoff time measurements. Those wafers meeting the electrical requirements were committed to the packaging operation.

Acceptable wafers were assembled into an Industry Standard TO-200AC flat package, vacuum baked and sealed with a cold welded lid. A package flouorocarbon leak test was followed by a thyristor final electrical test.

BENEFITS

Project achievements were demonstrated by a pilot line with a production rate of 20 units per 8-hour shift.

Due to the improved manufacturing processes established by this project, the cost per device was reduced from approximately \$300 to \$200.

IMPLEMENTATION

This thyristor device has direct application in any electronic circuit requiring high power SCRs, which includes high frequency inverters, phase control, power conditioning (15KVA) and the 100 kilowatt turbine generator. A final report containing process details, production check points and quality control safeguards was distributed to both Government and Industry.

MORE INFORMATION

Additional information may be obtained from Mr. Lane, US Army ERADCOM, Ft. Monmouth, NJ, AV 992-4965 or Commercial (201) 544-4965.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 273 9526 titled, "Low Loss, High Reliability Integratable PIN Diodes," was completed by the US Army Electronics Command in September 1976 at a cost of \$159,000.

BACKGROUND

At the time the project was initiated, there was no production source for high reliability integratable PIN diodes for phased array radars. (PIN refers to Positive, Intrinsic, Negative regions of the diode.) Process improvements were needed in epitaxial deposition techniques for making N+ and P+ regions of the diodes, in glass film application methods for junction insulation, and in substrate passivation techniques to minimize device contamination.

SUMMARY

Microwave Associates, Burlington, MA, contracted to develop a mass production process for producing both glassed planar and epitaxial mesa microwave diodes suitable for mass production attachment to phase shifter substrates.

Work resulted in the establishment of processes for controlled epitaxial growth of single-crystal silicon onto silicon wafers, for accurate diffusion of phosphorus and boron into the wafers to form N+ and P+ regions, and in glass film application methods for passivating the active surface. Use of these techniques resulted in improved diodes for high frequency applications. Process steps are illustrated in Figure 1.

In addition, the contractor built S-Band (3 GHz) and X-Band (9 GHz) microwave control circuits in which to test the units. Unpackaged diodes were attached to substrates in both S- and X-Band phase shifters and an S-Band switch/limiter, and met all RF requirements. Their reliability was equal to, or better than, other diodes and their ruggedness made them suitable for automated assembly.

Testing of PIN diodes was done on a system that consisted of an x-y controlled wafer handling table, a pickup mechanism for selecting chips from a scribed and broken wafer, a computer controlled radio frequency tester such as the HP 8542B, and means to place tested chips into a carrier. The carrier could be a segmented tray or a reel of adhesive film. Glassivated diodes were easy to handle and could be tested at the rate of several thousand per hour.

Work on this contract resulted in the development of procedures for controlled epitaxial growth of silicon onto silicon wafers in a float zone refiner while

minimizing impurities entering the material during processing. Also, in maintaining uniformity of material in the "intrinsic" region, a uniform junction width, and superior junction insulation.

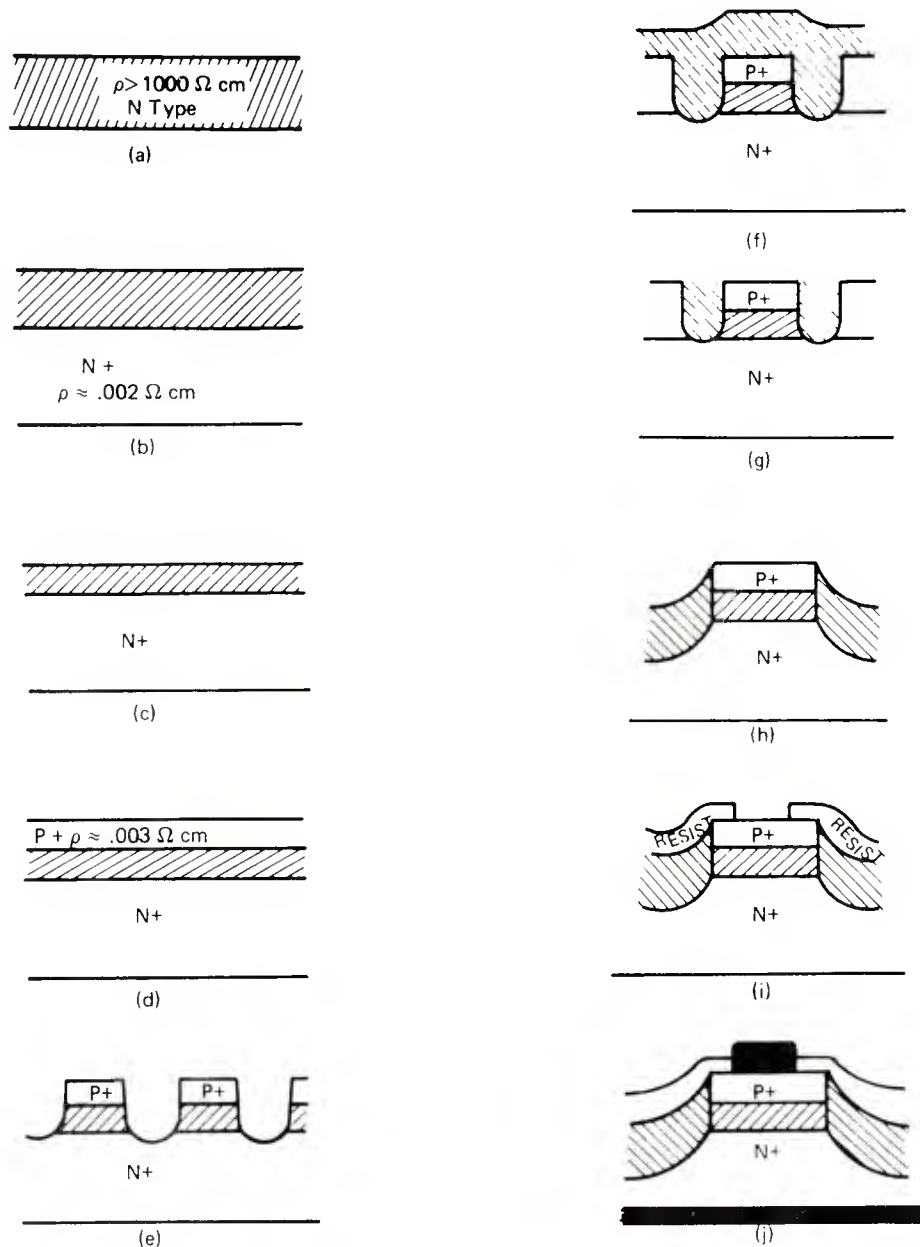


Figure 1 - Process I Glassed Double Epitaxial Mesa

BENEFITS

New glass film application methods provide a half mil of insulation to protect against contamination, moisture and handling damage. A cost reduction resulted from the elimination of the ceramic package that housed the diode; some packages cost more than the diode. A discounted 10-year savings of \$1,878K against a non-recurring cost of \$159K provides a S/I ratio of 12 to 1. Part of the saving resulted from the elimination of the ceramic packages that housed the diodes, and part resulted from reduced assembly labor.

IMPLEMENTATION

The contractor now uses the diffusion and passivation techniques developed on this project to manufacture PIN diodes for use at 3 to 9 Gigahertz frequencies. Unpackaged PIN diodes are now catalog items with Microwave Associates and other high frequency semiconductor houses. Diodes of this type are employed as phase shifters in the CAMEL phased array radar antenna, and in the Cobra Dane microwave antenna.

MORE INFORMATION

A final report on contract DAAB05-73-C-2064 titled, "Production Engineering Measure for High Reliability Integratable PIN Diodes," is available from Microwave Associates, and from DTIC. Mr. James Kelly, CECOM, was project engineer. AV 992-2682, Commercial (201) 532-2682.

Summary Report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 273 9575 and 274 9575 titled, "Automatic Assembly of Hybrid Circuits for Proximity Fuzes," was completed by US Army Electronics Command in June 1976 at a cost of \$422,000.

BACKGROUND

Electronic timing and logic circuits are replacing mechanical and electro-mechanical timers in artillery, mortar and grenade fuzes. Because fuzes are bought in quantities of several hundred thousand of each type per year, hand assembly methods are not cost effective. Semi-automatic and fully automatic methods are the only practical and economical way that these large quantities can be assembled and tested.

SUMMARY

The objective of the project was to automate and integrate two somewhat different processes; that of screening and firing small ceramic substrates, and of assembling components to the substrates to form fuze timing circuits. The first process includes screening, drying, and firing resistor and conductor patterns onto small ceramic substrates which are then stacked for further assembly.

The second process consists of orienting and placing small components such as diodes, chip resistors and capacitors, transistors, and integrated circuits onto the substrate conductor pattern to form the complete fuze circuit. Both processes had been automated on an individual basis, but had not been combined for high volume production. An automatic testing station was also required for complete electrical test of the circuit prior to further assembly into the fuze.

In addition to automatic component placement equipment, RCA used a GCA Model 1100 Programmable Wire Bonder to connect integrated circuit chips to the hybrid substrate. A complementary metal oxide semiconductor (CMOS) amplifier chip was used in each M734 multi-option fuze and these were wire bonded using the programmable wire bonder. The equipment is illustrated in Figure 1.

BENEFITS

The system was able to produce and test 125 fuze circuits per hour, or 20,000 per month, with a reduction in cost from \$250 on a laboratory scale to \$10 in production. Three thousand units were built, tested and supplied to Harry Diamond Labs for proof testing in the fuze.

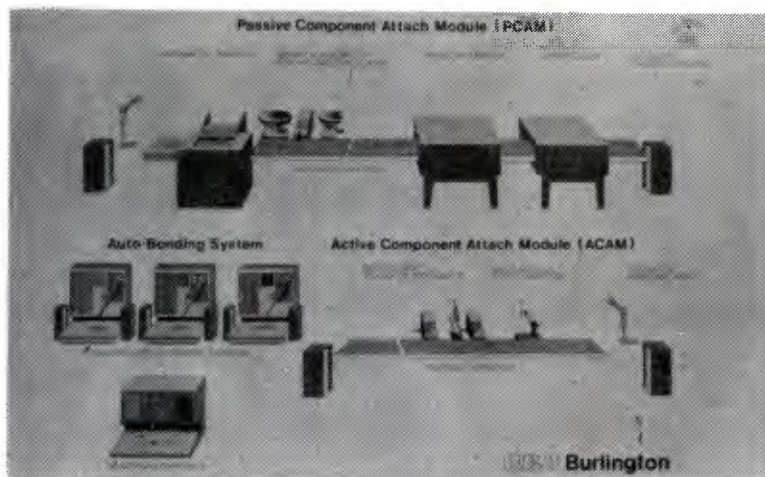


Figure 1 - Automated Hybrid Assembly

IMPLEMENTATION

Although RCA did not win the production contract for the M734 fuze, the equipment purchased with company funds for use on this contract is in use for other production, e.g., circuitry for the GVS-5 Laser Range Finder and several hybrids for EQUATE interface units.

MORE INFORMATION

Additional information may be obtained from Defense Technical Information Center by ordering the Final Report for Contract DAAB05-73-C-2039, AD number A0 22204, or from the project engineer, Mr. James Kelly, CORADCOM, AV 992-2682, Commercial (201) 532-2682 or from Mr. Brad Joyce at RCA, (617) 272-4000.

Summary Report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 273 9609 titled, "Manufacturing Methods and Technology Engineering Measure for Solid State Microwave Oscillators for Fuzes," was completed by the US Army Electronics Command in June 1976 at a cost of \$277,000.

BACKGROUND

Prior to contract award, solid state, narrow pulse UHF and S-Band TRAPATT diodes were unavailable outside the laboratory. This project's goals were to develop economical large-scale fabrication methods that would provide a uniform diode internal structure and insure boundary quality.

SUMMARY

The project's objective was to establish a manufacturing capability for narrow pulse solid state TRAPATT diodes operating at 800 MHz (UHF) and 4 GHz (S-Band). Hughes Aircraft Company, Electron Dynamics Division, demonstrated the technology by performing the following tasks:

1. Fabricated TRAPATT diode chips with minimum crystal damage.
2. Provided a detailed thermal analysis of the packaged diodes under adiabatic conditions.
3. Achieved a cost effective miniaturized 800 MHz circuit oscillator module using lumped element microwave integrated circuit (MIC) techniques.
4. Established a high power second harmonic extraction circuit oscillator module at 4 GHz.
5. Provided efficient solid state modulator circuits for biasing the diodes.

TRAPATT diodes were fabricated by a pill processing technique which provided the low thermal and parasitic resistance necessary for efficient trapped plasma state operation. The diodes utilized a p^+-n-n^+ silicon structure with deep-diffused junctions to achieve extremely high power levels without resorting to power combining techniques.

Doping profile measurements of the wafer epitaxial layer were made on a sample basis from each epitaxial run using an automatic profiler. An optimum doping profile for both UHF and S-Band devices was achieved.

Other processes optimized for production and lower manufacturing costs included

boron diffusion, oxide gettering, vacuum deposition of titanium and gold, photolithography, chemical etching, and gold and silver plating. Heavy duty diode operation was accomplished by utilizing this silver plated heat sink technology. Packaging for both diode types was essentially the same. The completed UHF diode package is shown in Figure 1. The etched chip (pill) with its silver plated heat sink is soldered to the stud package base. Gold ribbon leads were attached to the chip and upper package flange by thermocompression bonding. The UHF package is hermetically sealed by welding, and the S-Band package by (cap) soldering. The S-Band package is shown in Figure 2.

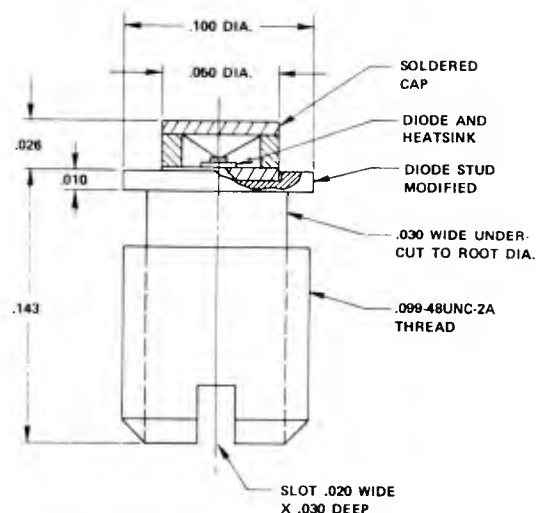
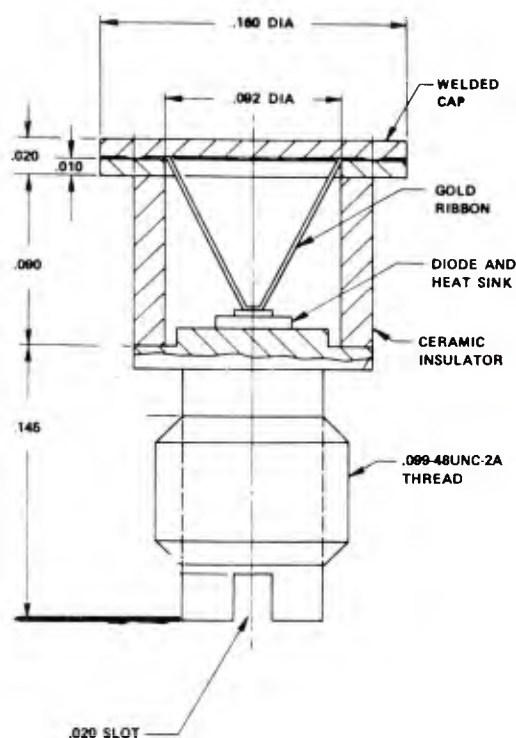


Figure 2 - S-Band Packaged TRAPATT Diode

Figure 1 - UHF Packaged TRAPATT Diode

In addition to the diode processing steps, contract effort was expended on oscillator and modulator modules. The UHF oscillator module design provided a low cost miniaturized circuit with a wide frequency tunability range, maximum power, and efficiency. S-Band impedance characteristics aided in construction and optimization of the coaxial, oscillator circuit module. Second harmonic power extraction techniques were employed for power extraction from the diodes at 4 GHz. An extensive environmental analysis of both oscillators was performed. Consistent results leading to advancement in the state-of-the-art for both TRAPATT diode and circuit development including impedance matching were achieved. Power levels of at least 300 watts were routinely obtained at 0.8 GHz with a minimum 25% efficiency. Power levels of 50-90 watts were routinely generated at 4 GHz with a minimum 15% efficiency. Maximum operating duty cycle, however, was limited to 1% for the UHF and 2% for the S-Band due principally to the pulse modulator design. The leading edge jitter obtained varied from 0-10 nanoseconds. Figure 3 shows the UHF oscillator (containing TRAPATT diode), matching cable, and solid state modulator module.

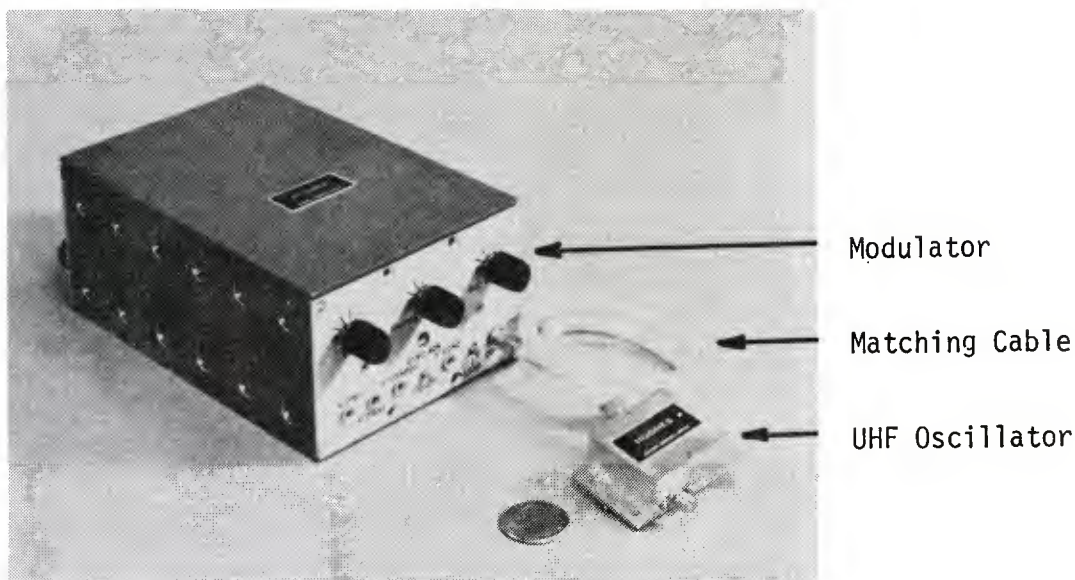


Figure 3 - UHF Oscillator - Solid State Modulator Module

BENEFITS

As a result of this effort, manufacturing capability for solid state, narrow pulse TRAPATT diodes now exists. The diodes may be purchased for approximately \$50 each in quantities of 100.

IMPLEMENTATION

The contractor's results have been documented and furnished to 14 advanced semiconductor firms and 16 Government offices. Devices are available for system designers to incorporate into new designs.

MORE INFORMATION

Additional information may be obtained from Mr. James Kelly, CORADCOM, Ft. Monmouth, NJ, AV 992-2682 or Commercial (201) 532-2682. The contract was DAAB05-73-C-2070.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 274 9753 and 275 9753 titled, "Manufacturing Methods for the Production of Beam Lead Sealed Junction Devices," were completed by the US Army Electronics Command in December 1977 at a cost of \$1,698,000.

BACKGROUND

Beam-Lead Sealed Junction (BLSJ) semiconductor technology was developed at the Bell Telephone Laboratories. The device structure utilizes a unique mechanical configuration which allows passivated chips to be bonded directly to printed substrate interconnect patterns. Plated gold beams, an integral part of the chip metallization, are approximately one half mil. thick and extend four mils beyond the chip edge. The unpackaged chip is bonded face down to the metallized pattern, with the beams furnishing both mechanical support and electrical connection. See Figure 1. Passivation of the semiconductor surface is required to prevent degradation.

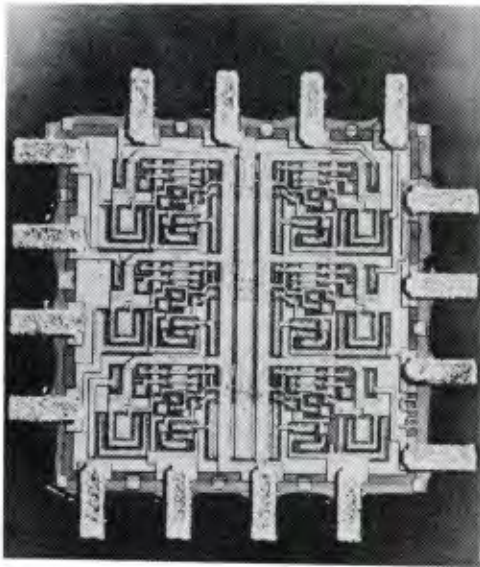


Figure 1 - Beam Lead 5404 IC Chip

A previous beam lead MMT project, 270 9300, was conducted on bipolar, TTL 5400 family IC devices, but was unsuccessful. This project's goal was to expand the previous work to include Schottky 5400LS TTL ICs, and also discrete devices.

SUMMARY

This project's objective was to establish and optimize production processes for semiconductor devices using beam lead sealed junction technology. The work

was performed by the Motorola Corporation Semiconductor Group, Phoenix, Arizona, and was divided into two phases.

Phase I consisted of an investigation and survey of the Solid State Industry and its capability to fabricate BLSJ devices. Existing processes, capacity, current yield, and actual device availability were determined.

Phase II established refined manufacturing processes for both discrete and integrated circuit BLSJ components. The discrete devices included zener, and field-effect current regulator diodes, PNP, NPN and P channel junction FET transistors. The integrated circuits (ICs) consisted of various gates, inverters and counters, all in the 5400 TTL family. The ICs were modified using Schottky diodes rather than the standard gold doping process to achieve the necessary speed-power products.

Engineering, first article and pilot production samples were required for 35 configurations; 14 discrete devices and 21 integrated circuits. Goals were to achieve minimum yields in the pilot run as follows: discrete - 20 percent; ICs - 10 percent; and 60 gate array - 5 percent. Work was performed in the areas of epitaxial growth, diffusion, metallization, photolithography, fluorine plasma etching, gold plating, wet nitrogen baking, lapping, and passivation. Metallization was accomplished by sequential RF sputtering of high purity platinum and titanium, followed by gold plating. The process flow for ICs is depicted in Figure 2.

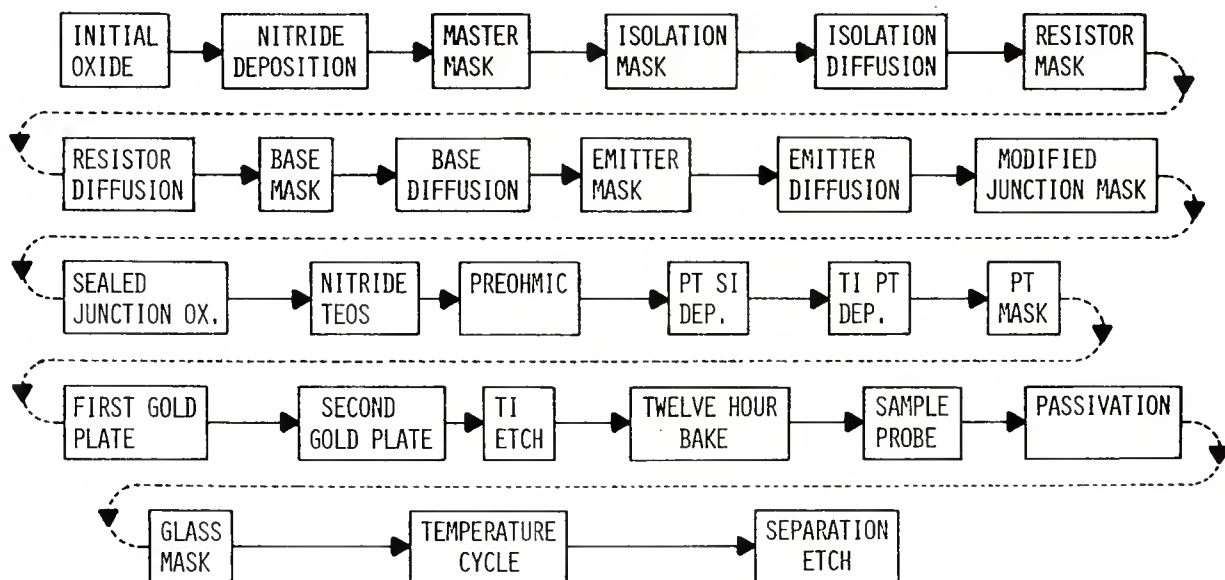


Figure 2 - Process Flow Chart For IC Beam Lead Devices

The work scope was reduced prior to contract completion and a number of devices were deleted after satisfying the engineering and first article requirements. Only five specific devices (3 discrete and 2 ICs) were selected for the pilot run. They were the IN746 zener diode, 2N3960 NPN and 2N4260 PNP transistors, RA 108 and 5404 ICs.

Motorola was unsuccessful in achieving the 20 percent yield goal on any of the discrete devices. Beam leads with top collector contact are inverted from standard chip and wire devices. The primary problem was caused by the long duration, high temperature, deep P^+ collector diffusion cycle needed for $V_{CE}(sat)$ requirements. During this cycle, substrate outdiffusion into the epitaxial layer occurred which caused undesirable device parameter changes.

The RA 108 sixty gate array IC failed both first article and pilot production tests. The chip was designed with Schottky diodes which require more space for a cell than was available. Failure occurred due to metallization shorts caused by reduced spacing between lines.

The 5400 and 54LS circuit family devices achieved respectable yields even on the more complex functions. Variations in diffusion times and temperatures for these ICs were not as critical as for the discretes, since most of the IC electrical parameters have much broader ranges. The 54LS (Schottky) devices had first article yields between 22 percent and 65 percent. The 5404 IC pilot run achieved a 61.3 percent yield for first article and 47.3 percent yield for pilot production. This is the device shown in Figure 1.

BENEFITS

The contractor demonstrated that specific Beam Lead 5400 and 54LS (Schottky) ICs could be fabricated in a production environment. The work on the discrete devices and the RA 108 gate, however, was unsuccessful.

IMPLEMENTATION

Project results on the 5400 and 54LS Beam Lead ICs were not implemented because of industry indifference. The contractor has filed a patent report but has stated that it will not be pursued. As of this writing, wire bonding is still the dominant technology, and wide implementation of technologies such as beam lead lies in the future. Long term use of beam lead will probably be in the microwave field where beams offer unique advantages.

MORE INFORMATION

Additional information may be obtained from Mr. James Kelly, CORADCOM, Ft. Monmouth, NJ, AV 992-2682 or Commercial (201) 532-2682. The contract was DAAB07-75-C-0033.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 277 9808 titled, "Automatic In-Process Evaluation of Thick Film Printing and Hybrid Circuit Assembly," was completed by the US Army Electronics Research and Development Command in January 1981 at a cost of \$576,340.

BACKGROUND

Hybrid devices utilizing standard integrated chips, custom interconnection and ceramic substrates containing pointed conductors and components are finding increased use in military systems where size and weight are critical parameters. The close tolerances and high reliability requirements for printed circuits necessitate a high level of inspection; in some operations, as much as 100%. Present manual inspection methods are labor intensive and fatiguing. A need exists for an automated method of in-process inspection to lower cost, improve yield, and assure a high degree of quality control for hybrid circuits.

SUMMARY

The objective of this project was to establish an automated system for inspecting thick-film conductor lines on hybrid substrates. The work conducted included: (1) System analysis investigating hybrid image extraction techniques, illumination techniques, and Return Beam Vidicon (RBV) operating modes to establish the basis for Automatic In-Process Microcircuit Evaluation (AIME); (2) Designing the AIME demonstration model, system software, and test program; (3) Fabricating the demonstration model (Figure 1); (4) Documenting the demonstration model. The data package included a test and inspection report, an instruction manual, engineering drawings, equipment specifications, and program listings.

The system is made up of two basic modules, the control/display station and the inspection station. Components for the control/display station include computer and peripherals, video processor and I/O control, RBV electronics, sync generator, time base corrector, video-disc recorder/reproducer, and video monitor. Components making up the inspection station include RBV camera, illuminators, holding fixture, optical table and air conditioner.

Analysis was made of typical characteristics of hybrid thick-film substrate conductor faults resulting from printing, probing and work-in-process handling. Based on this analysis, test sample substrates containing designed-in-faults were fabricated and used to evaluate the AIME.

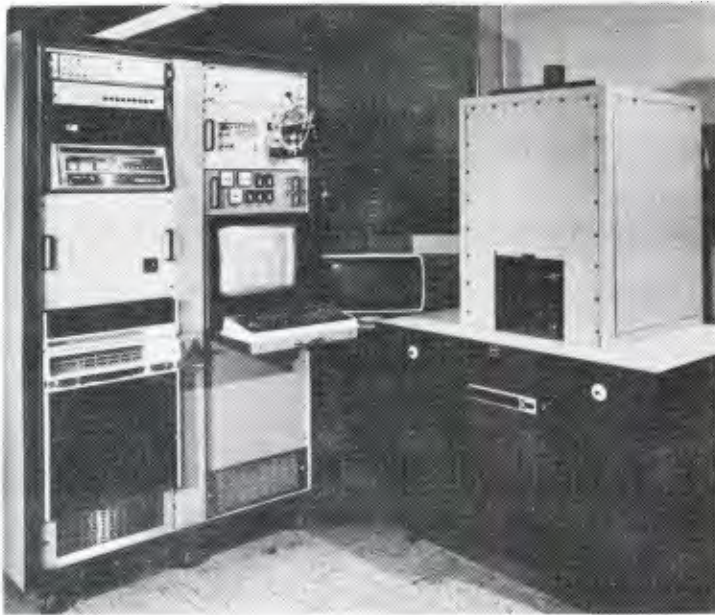


Figure 1 - AIME SYSTEM

BENEFITS

It has been demonstrated that an electro-optical system can be used for automatic quality control inspection of thick film networks for military hybrid microcircuits. The technique has demonstrated that automatic inspection of substrates is feasible and has the potential to replace visual inspection of hybrid microcircuits with microscopes which is slow and fatiguing. The technique can inspect hybrid substrates at rates of 750 per hour, and its efficiency makes 100% inspection an economical method for quality control at high through-put rates. Automation will reduce the cost of inspecting hybrid microcircuits. At present, manual visual inspection accounts for 10-15% of the cost of fabricating a military hybrid microcircuit.

IMPLEMENTATION

A detailed final report which defines the hardware instrumentation, software development and includes functional inspection results, has been completed and distributed throughout the hybrid microcircuit industry and equipment (fabrication and testing) manufacturers.

MORE INFORMATION

A copy of the final report titled, "Manufacturing Methods and Technology Program Automatic In-Process Microcircuit Evaluation," (DELET-TR-77-0585-F) dated October 1980 is available. Contact Mr. I. H. Pratt, ERADCOM, AV 995-2308 or Commercial (201) 544-2308.

Summary Report was prepared by J. H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT - 302)

Manufacturing Methods and Technology projects E78 3605, E79 3605, and E80 3605 titled, "Transcendent High-Power Transistor," were completed by the US Army Mobility Equipment R&D Command, Ft. Belvoir, VA, in January, 1981, at a total cost of \$534,000.

BACKGROUND

Semiconductor switches used in high current power conditioning equipment require large heat sinks with fins to conduct the heat to an outside air stream. Their bulkiness is a hinderance to good clean design and small package size. Heat pipes are a new innovation that make use of the large heat-absorbing capacity of an evaporating fluid. Water or freon is fed to the heated surface where it evaporates and cools the area; the vapor is conducted to a cooler area where it condenses and returns by capillary action to repeat the cycle. This is done in a heat pipe with porous copper wicking and requires no moving parts.

A manufacturing problem related to the interdigitated emitter ballasting wafer also had to be solved. Alignment of the spoke-like ballast wafer with the similarly designed transistor wafer had to be engineered for volume assembly.

SUMMARY

The contractor developed specialized fixtures and procedures for rapid fabrication of heat pipes and for bonding the bases of two heat pipes to opposite sides of a silicon transistor wafer. High temperature brazing of the heat pipe body, sintering of porous wicks, and ceramic-to-metal sealing were production engineered to permit volume manufacture. Plating, lapping and soldering methods were tailored to obtain blister-free, void-free metal joints between the heat pipes and the transistor wafer.

Each heat pipe consists of a molybdenum disc in contact with the silicon transistor wafer, a cylindrical porous copper body which serves as the wick, and a copper end closure and spiral fin assembly that forms the outside walls. A cutaway diagram, Figure 1, depicts this assembly.

Shown in Figure 2 is the interdigitated emitter ballast which is aligned with the similarly interdigitated transistor wafer during assembly. The ballast must be aligned exactly and maintained that way during welding of the enclosure to insure uniform distribution of current throughout the silicon chip. Tooling was developed to achieve this precise alignment, and test equipment was assembled to assure it.

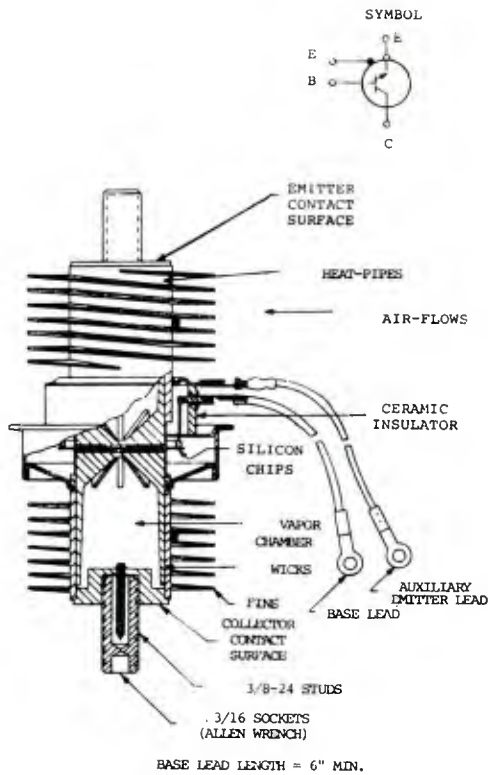


Figure 1 - Silicon Transistor Disc With Heat Pipes Attached To Each Side

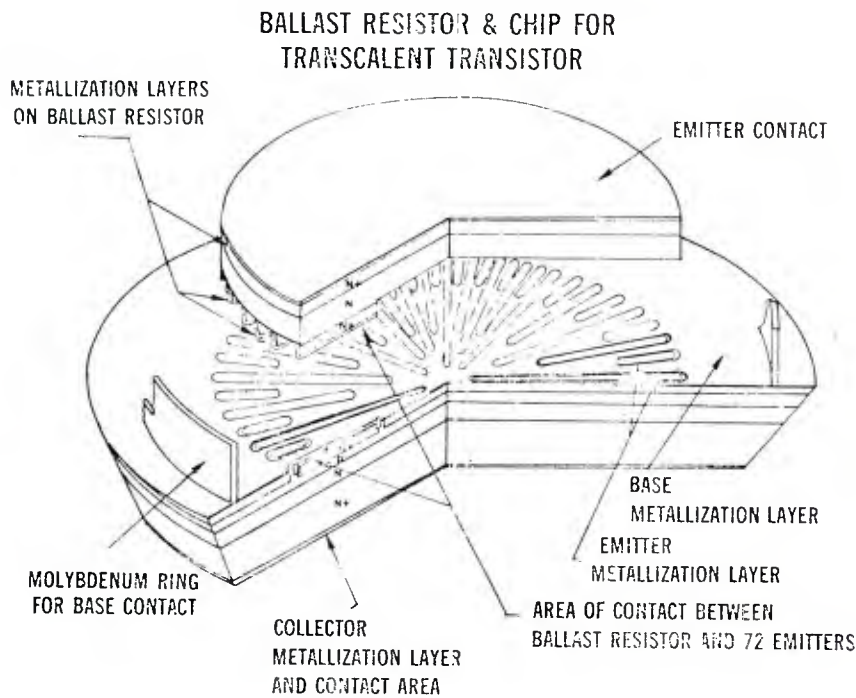


Figure 2 - Interdigitated Transistor Wafer And Interdigitated Emitter Ballast

BENEFITS

The use of heat pipes extends the current switching capability of a semiconductor by cooling its junction to permit higher current density without damage to the device.

Cost of a typical high power transistor was reduced from \$2380 when built on a laboratory scale, to \$300 when produced in volume.

The double-sided heat pipe is inherently rugged and can be installed in field type equipment. Torquing the device is not a problem as it was with the hockey puck type transistors it replaces, and relaxation of clamping force through creep of copper or aluminum parts does not occur.

The transistors are being evaluated by Lockheed for use in Navy torpedoes and by the Department of Energy for use in power inverters used with solar cells.

IMPLEMENTATION

MERADCOM has several sample high power transistors available for loan to potential users who wish to determine their suitability in items being developed for the Army. A brochure highlighting features of transcalent devices was developed and circulated by MERADCOM. RCA published data sheets on the units and has an active applications engineering department. Video tapes on assembly are also available from RCA.

MORE INFORMATION

A final report on contract DAAK70-79-C-0019 titled, "MM&T Measure for Fabrication of Silicon Transcalent Transistor," is available from RCA Corporation, Solid State Division, New Holland Avenue, Lancaster, PA 17604. Mr. Frederick G. Perkins, MERADCOM, Ft. Belvoir, was project engineer. AUTOVON 354-5724. Commercial (703) 664-5724.

Summary Report was prepared by C. E. McBurney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project R78 3171 titled, "Development of Automatic Monitoring and Control for Wave Soldering Machines," was completed by the US Army Missile Command in February 1981 at a cost of \$450,293.

BACKGROUND

Wave soldering is used in the electronics industry for soldering printed wiring assemblies. Tens of thousands of joints can be soldered per hour by this process. If a process variable goes out of control, many defective joints can result in a short time. Satisfactory soldering in the wave soldering process depends upon a combination of interacting conditions and materials including solderability, flux activity, flux application, preheat source temperature, conveyor speed, solder temperature, solder wave shape, area of contact, solder wave surface conditions and the heating rate of the assembly itself. The process of selecting a set of conditions to solder a particular assembly is based mainly on experience of the operator supplemented by trial and error. On most wave solder machines, only temperature is controlled while the other variables are fixed and presumed to remain constant. Since no measurements are made, except for temperature, changes in conditions may go undetected allowing the production of many defective joints.

SUMMARY

The objective of this project was to identify the parameter limits necessary to prevent the most frequent solder defects and establish a system for monitoring and controlling these parameters. The wave soldering process as applied to military-quality printed wiring assemblies was critically examined for ways of improving and simplifying it. This resulted in the following modifications:

1. Fixturing that offers better protection for the board and reduced sensitivity to the wave flow characteristics.
2. A fluxing method that applies fresh, instead of recirculating, flux with a coverage that is thinner and controllable by means of an airless spray.
3. The elimination of preheat made possible by the above fluxing method.
4. Reduction in the rate of dross formation by running the solder pump only when needed.
5. Reducing to one (namely conveyor speed) the number of process conditions that change with board style.

Virtually all of the duties currently performed by the wave soldering operator have been assumed by the automated control system developed under this project. These eliminated duties include:

1. Turning on the solder heat, solder pump, preheat, fluxer and conveyor.
2. Measuring flux specific gravity.
3. Adjusting the height of flux foam or wave.
4. Checking to verify that solder temperature and wave height are correct.
5. Setting conveyor speed for each style of board.
6. Cleaning the board in a vapor degreaser.
7. Completing the paperwork that accompanies the board.
8. Keeping records on equipment operation, maintenance and repair.

Addition of a microcomputer to the system provides for communication with the factory computer system for centralized maintenance of an inventory data base and for setting the proper conveyor speed; automatic computer entry of board identity by means of a bar code label; measurement of flux flow, conveyor speed, and temperature to verify proper system operation; and, presentation of system error messages on a video display screen.

BENEFITS

The production evaluation of the wave solder machine has demonstrated that the modification to it and to the process are cost effective. It is estimated that annual cost savings for inspecting and touch-up of wave soldered printed wiring assemblies will exceed \$1 million at Westinghouse Electric Company.

IMPLEMENTATION

The automatic wave soldering system was installed at Westinghouse Electric Company, Baltimore, Maryland. Systems supported at Westinghouse include DIVADS, RPV, F16 and ALQ131.

MORE INFORMATION

Additional information and a copy of the final report, "Automatic Monitoring and Control System for Wave Soldering Systems," dated October 1980, is available from Mr. Lloyd L. Woodham, US Army Missile Command, AV 746-1572 or Commercial (205) 876-1572.

Summary Report was prepared by J. H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects R78 3242 and R79 3242 "MM&T Digital Fault Isolation of Printed Circuit Boards," were completed by the US Army Missile Command in December 1980 at a cost of \$850,000.

BACKGROUND

The growing use of LSI devices (microprocessors, RAMS, ROMS) has increased the need for more efficient and economical production testing of the printed circuit boards (PCBs) in which they are contained. These boards are difficult to test due to the inherent design itself and to the myriad of functions they perform.

The loop between the microprocessor and its ROM/RAM memory elements tends to inhibit fault isolation, and the use of a bi-directional data bus requires the test system to be interactive at times. Many of the logic devices require board dynamic testing at normal operating clock rates to explore all possible fault conditions. Finally, the test system is software intensive for providing proper stimulus to the board under test and interpreting its responses.

SUMMARY

The project's objective was to establish an automatic test and fault diagnostic system for complex digital PCBs containing microprocessors, RAMS and ROMS. Goals were functional testing to 95 percent comprehension (ability to detect all faults) and fault isolation to the pin level of LSI devices or hybrid modules. Simulated digital PCB faults included SAO, SA1, SB (Solder Bridge) and two simultaneously introduced faults. The work was performed by Hughes Aircraft Co., Fullerton, CA, and was divided into two phases.

Phase I was an investigation into industry's digital PCB test requirements and test system capabilities. The baseline equipment surveyed consisted of seven major PCB test systems and 21 digital PCBs derived from six prime military systems. This evaluation resulted in selecting the Hewlett Packard DTS-70 as the optimum automatic test equipment (ATE) for production testing, Figure 1. The system contains the HP 1000/40 computer and 20 M byte disc drive (7906/020). One HP 1000/40 computer can operate three test stations with six operator terminals including three terminals on a time-sharing basis.

Phase II demonstrated the technology by employing an adapted DTS-70 system, enhanced with a HP 5004A Signature Analyzer. Tasks comprised developing specific hardware and software needed for testing the two worst case microprocessor PCBs, P/N 1635972 and P/N 1646178 determined in Phase I. The boards are part of

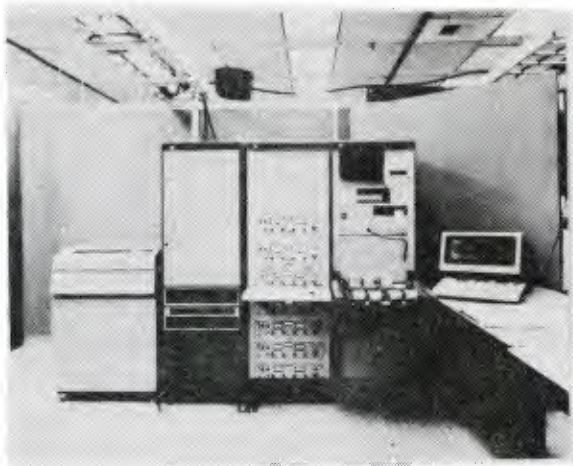


Figure 1 - DTS-70 System Configuration for the Digital Fault Isolation Program

military systems in current production, the Army AN/TPQ-36 Radar and the Navy HMD-22 ADGE Radar Display.

Two independent test processes were required to test the 1635972 board, Figure 2.

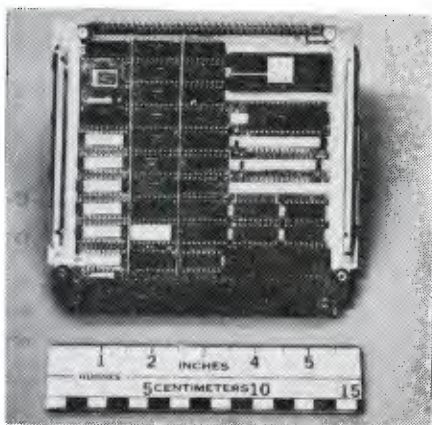


Figure 2 - 1635972 D/PCB. This board with 3 LSI devices (including the 8080A/B microprocessor) and 28 ICs was able to stress the DTS-70 system's test and fault isolation capabilities.

This assembly contains the 8080 A/B microprocessor which was not modeled in the HP library nor was it feasible to be modeled within the time allotted. Signature Analysis was used to test the 8080 A/B microprocessor while HP's TESTAID/FASTRACE software was used to test the remainder of the board with the microprocessor removed from its socket. TESTAID/FASTRACE test software for the 1635972 board was used for three major tasks: modeling, test pattern generation, and interfacing the bi-directional I/O data base. The 175 test patterns required were manually generated and provided an overall test comprehension of 98 percent.

The development of the 1635972 board test program required 46.1 man-weeks and resulted in a fault isolation time between 0.2 and 5.9 minutes for any fault. Complete GO/NO-GO functional test time was the sum of Signature Analysis - microprocessor manual probing (8.0 minutes) and TESTAID/FASTRACE (0.3 minutes) which totalled 8.3 minutes.

The 1646178 board, Figure 3, was tested entirely with software based on TESTAID/FASTRACE. A model for the 16 bit, AM2901 microprocessor was constructed

and the complete board test was executed in four subdivisions. Test software utilized 2,586 manual test patterns and achieved an overall test comprehension of 90 percent. A Hughes software package, SPEDUP, was used to reduce average TESTAID simulation time by almost 66 per cent and overall disc storage space by 50 percent. SPEDUP can also be applied to other generic digital PCSs.

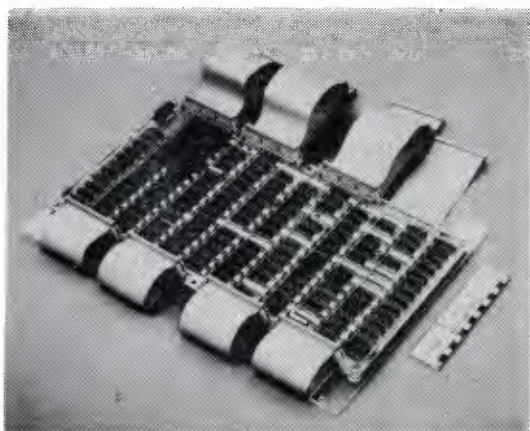


Figure 3 - 1646178 D/PCB. This 9" x 16", HMD-22 board, with its four AM2901 LSI microprocessors and 142 IC devices, provides a thorough test of the DTS-70 system's ability to detect both microprocessor and sequential logic faults.

The development of the 1646178 test program required 28.4 man-weeks and resulted in a fault isolation time of between 0.2 and 11.84 minutes for any fault. Complete GO/NO-GO functional test time was 1.5 minutes.

The electrical and mechanical interface required between each board and the DTS-70 was obtained by modifying HP 9107A adapters. Support maintenance and performance data on the DFI Test System was provided by Hughes' application of HP's IMAGE/1000 Data Base Management Program.

BENEFITS

In general, benefits realized include improved techniques for detection, identification and location of faults in complex digital PCBs having mixed logic, LSI and microprocessor devices. Diagnostic capability extended from the circuit node to the component level, decreased board testing time and significantly reduced cost.

IMPLEMENTATION

The project's results will be utilized for testing 218 different type digital PCBs in five military systems including the Army AN/TPQ-36 Radar and the Navy HMD-22 ADGE Radar Display.

MORE INFORMATION

Additional information may be obtained from Mr. Gordon Little, MICOM, Redstone Arsenal, AL, AV 746-3848 or Commercial (205) 876-3848. The contract was DAAK40-78-C-0290.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project R79 3272 titled, "Flexible Printed Circuits With Integral Molded Connectors (FLEXICON)," was completed by the US Army Missile Command in December 1980 at a cost of \$193,545.

BACKGROUND

Flexible Printed Wiring (FPW) and Flat Conductor Cable (FCC) are technologies which have been in use for many years. However, the available processes for termination to mil-qualifiable connectors, particularly for humid airborne environments, were expensive, difficult to control and not cost effective. Advancement was needed in FPW/FCC termination techniques, connector design, and molding materials.

SUMMARY

The project's objective was to establish high speed, low cost automated processes for terminating flexible printed wiring to connectors (FLEXICON), such as shown in Figure 1. Westinghouse Electric Corporation at Baltimore, MD, performed the work. Optimum processes and materials were selected for integration with an automated facility to produce 500 units per eight-hour shift, or one per minute.

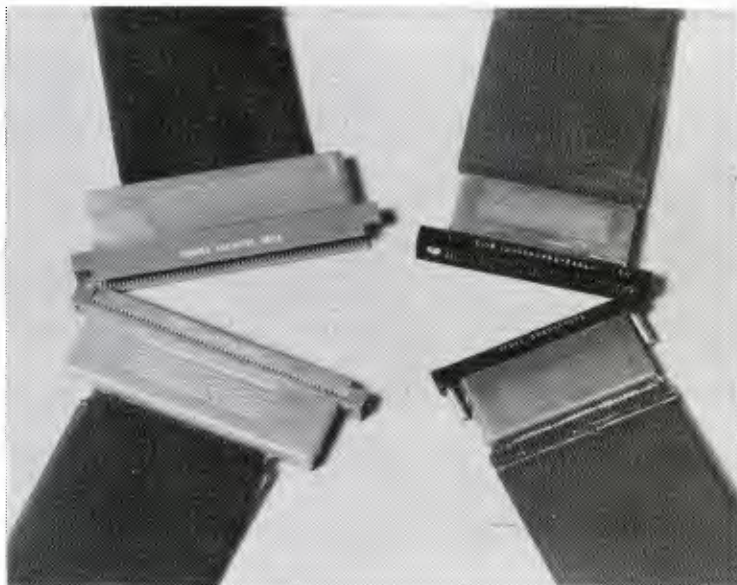


Figure 1 - Molded FLEXICON
Assemblies for Two Connector
Families

A three-process setup was developed: insulation removal by laser ablation, termination by laser welding, and sealing and strain relief by high speed liquid injection molding.

Various molded connectors were used to evaluate molding materials for adhesion and flexibility. The molding compound selected was a Hydantoin epoxy resin modified with a diglycidyl ether, a flexible anhydride hardener and two amine catalysts.

LASER ABLATION - A CO₂ pulsed 10.6 micron wavelength laser was used for stripping organic insulation material from FPW leads. The insulation absorbs the laser energy and is vaporized leaving the copper conductor undisturbed. A fine ash residue left behind is easily removed with a solvent rinse accompanied by a light brushing. Under X-Y numerical controls, only a few seconds are required to expose a .250 x 2.0 inch window, see Figure 2.

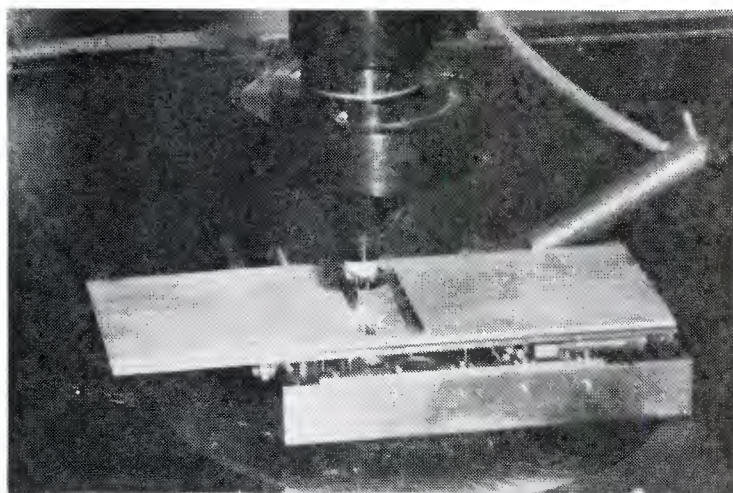


Figure 2 - Removal of Organic Insulation by CO₂ Laser Ablation is a Rapid Process

LASER WELDING - A ND:YAG pulsed 1.06 micron wavelength laser was used for welding copper FPW leads to the contact pin tails of the connectors. This technique resulted in a highly reliable joint with a tolerant weld schedule. The laser welds had superior strength when compared to normal welds. A tension test proved that the laser welds had greater strength than the basic copper track on the FPW.

HIGH SPEED LIQUID INJECTION MOLDING - Planar dual-row connectors with 40 pin contacts per row on 0.050 inch centers were used for the high speed liquid injection molding operation. Encapsulation provided the necessary sealing, electrical isolation between leads, and strain relief transition from connector to unsupported FPW. A quick cure liquid resin system was used and made possible automatic mold loading and encapsulation of FLEXICON assemblies in line with the preceding process steps.

The Hydantoin epoxy resin molding material selected met all the adhesion, flexibility, hardness, rapid cure and environmental requirements. It also adequately withstood the 150° C, low pressure, five-minute mold cycle. A view of the mold during the five-minute press cycle is shown in Figure 3.

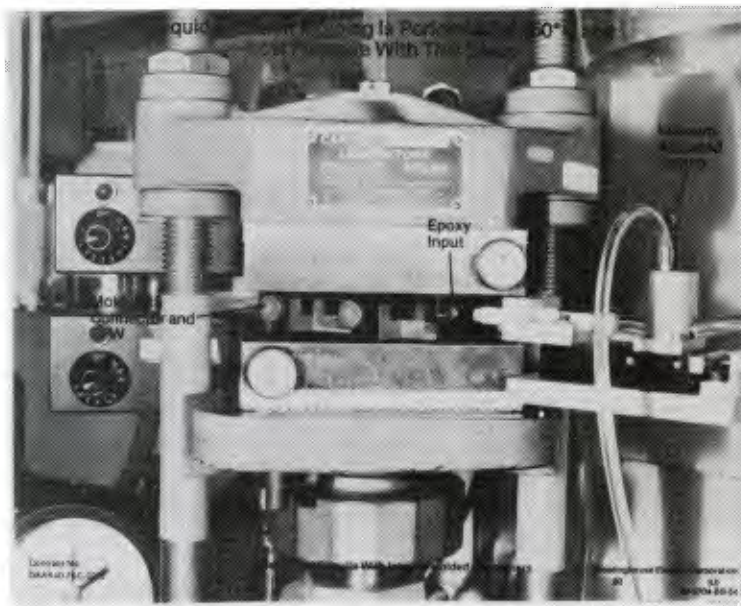


Figure 3 - Liquid Injection Molding is Performed at 150°C and Low Pressure With This Equipment

BENEFITS

Flexible printed wiring saves 80% of the weight, 20% of the volume and 30% to 50% of the interconnection cost in many military assemblies. The basic savings for military environment qualifiable connectors is shown below. These are the amounts that would be realized once implemented in a fully automated FLEXICON production facility.

COST COMPARISONS OF CONNECTOR ASSEMBLIES

	<u>Present Practice</u>	<u>FLEXICON</u>
Connectors (Mated Pair)	\$450.0	\$50.0
Flexible Printed Wiring (4 layers)	80.0	45.0
Assembly (Value Added)	90.0	4.0
Maintenance Expenses	1.2	0.2
	<u>\$620.2</u>	<u>\$99.2</u>

IMPLEMENTATION

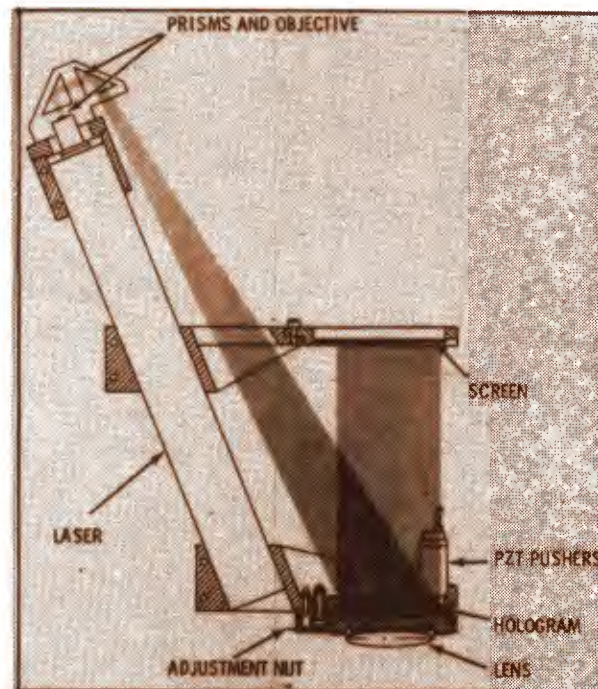
The project results were implemented in the AN/ALQ-131(V) and E3A-AWACS Radar in an on-board test equipment update. They are also scheduled for incorporation in the APG-66 - Advanced Signal Processor I/O Cable (Production in 1981) and AQUILA - Army RPV Sensor - (pre-production in 1981).

MORE INFORMATION

Additional information may be obtained from Mr. Gordon Little, MICOM, Redstone Arsenal, AL, AV 746-3848 or Commercial (205) 876-3848. The contract was DAAK40-79-C-0212.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, Industrial Base Engineering Activity, Rock Island, IL 61299.

INSPECTION AND TEST



OPTICAL HOLOGRAPHIC TEST EQUIPMENT

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 37T 3115 and 377 3115 titled, "Engineering for Metrology and Calibration," was completed by the US Army Missile Command in February 1981 at a cost of \$651,000.

BACKGROUND

This project is a continuing effort to devise new measures and calibration technology consistent with advances in manufacturing processes, techniques and equipment to support Army requirements. Measurement science must be continually advanced in relevant technology areas to keep pace with Army program requirements. Advancements in metrology must be made by increasing precision and accuracy of existing standards and by deriving new standards, processes, and techniques.

SUMMARY

This effort consisted of the following tasks:

- Josephson Effect Voltage Standard
- Variable Omni-Range (VOR) Navigation
- Low Frequency RMS Voltmeter
- Automatic AC/DC Thermal Voltage Measurement System
- Pressure Transducer System
- Microprocessor Technology
- Repeatability Study for Low Flow Turbine-Meters
- Modular Equipment Configuration for Calibration and Analysis
- Instrument Controller System
- Modern Electro - Optical Technology
- Interlaboratory Comparison of Electro - Optical Standards
- Six-Port Measurement Systems
- Microwave System Standards

Of these tasks, only three were completed, one was terminated, with the remaining nine being continued. The following tasks are representative of the objectives and results of the work accomplished by this project.

Instrument Controller System

The objective of this effort was to assemble a time-shared, instrument controller to control programmable instruments. This multiple work station system is required to support a number of metrology and calibration real time controlled processes and tests. With the use of existing equipment, including the central processing unit and mass storage media, and with purchased equipment for each work station, the system was assembled and tested. The results of this effort demonstrated that the time-shared instrument controller concept is feasible in a hardware environment.

Microwave System Standards

The objective of this effort was to test and evaluate the Weinschel Model 4310 AK-16P Multiband sweeper system, and the Hewlett-Packard Model 436A Power Meter. These instruments were identified as having high potential for the Army's Microwave Calibration Program. Both of these instruments were tested in the laboratory and used to perform actual calibrations. These units were found to be adequate as stand-alone instrumentation for the Army's Microwave Calibration Program.

BENEFITS

The benefits realized by the Army from these efforts are as follows:

Instrumentation Controller System - The results of this effort produced an instrumentation controller system that has the capability to be used in a hardware environment.

Microwave System Standards - The results of this effort demonstrated that the Weinschel 4310AK-16P Multiband Sweeper System and the Hewlett-Packard 436A Power Meter are adequate to perform microwave calibration measurements.

IMPLEMENTATION

Instrumentation Controller System is currently being used for laboratory purposes; however, other applications are being considered for implementation at the US Army Metrology and Calibration Center, Huntsville, AL.

Microwave System Standards

The Multiband Sweeper System was selected for use in the Army's Primary Standards Laboratory. Also, the system is being fielded as part of the Reference and Transfer Microwave Calibration System. The Power Meter is being used in calibration support at the Army Standards Laboratory and in engineering of standards by the US Army Metrology and Calibration Center, Huntsville, AL.

MORE INFORMATION

To obtain more information, contact the project officer, F. B. Seeley, MICOM, AV 746-5638 or Commercial (205) 876-5638. A final Technical Report AM CC-MS-80-6 titled, "Final Technical Report for Manufacturing Methods and Technology Project 377 3115 Engineering for Metrology Calibration" was published by the US Army Missile Command, December 1980.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 575 1284 and 576 1284 titled, "Improvement and Modernization of Inspection Aids for Defense and Protective Items," were completed by the US Army Armament Research and Development Command's Chemical System Laboratory in January 1981 at a cost of \$424,000.

BACKGROUND

These projects were initiated to modernize and improve the chemical and biological (CB) defensive and protective equipment, Q127, Penetrometer Filter Tester. This tester has been used in its present configuration since prior to World War II to perform in process, final, and surveillance testing. The only improvements that have been made to this tester resulted from the unavailability of obsolete components. Since the development of this filter tester, many electronic and optical technological advancements have been made that would aid in modernizing and improving the tester's capabilities. The modernization of this tester will insure a higher level of quality in CB defense and protective equipment.

SUMMARY

The objective of this effort was to design, develop and fabricate a Penetrometer Filter Tester that would have improved reliability, accuracy, sensitivity, and operating efficiency. This tester would have the capability to control feedback and automatic compensation for voltage irregularities which would provide stabilized operating parameters. The results of this effort produced a XQ127A1 prototype tester, Figure 1, that has the following improvements:

1. Calibration of this tester requires a minimum amount of time to perform;
2. Operation process consists of 15 steps versus 48 steps for the Q127;
3. Test Monitoring, particle size, distribution width, temperature percent penetration, and flow rates are readily observed with minimum drift;
4. Equipment Configuration: size and weight is such that the tester may be moved with little difficulty.

BENEFITS

The results of this effort demonstrated that a Penetrometer Filter Tester can be modernized and improved to increase reliability and accuracy with increased quality of end items.

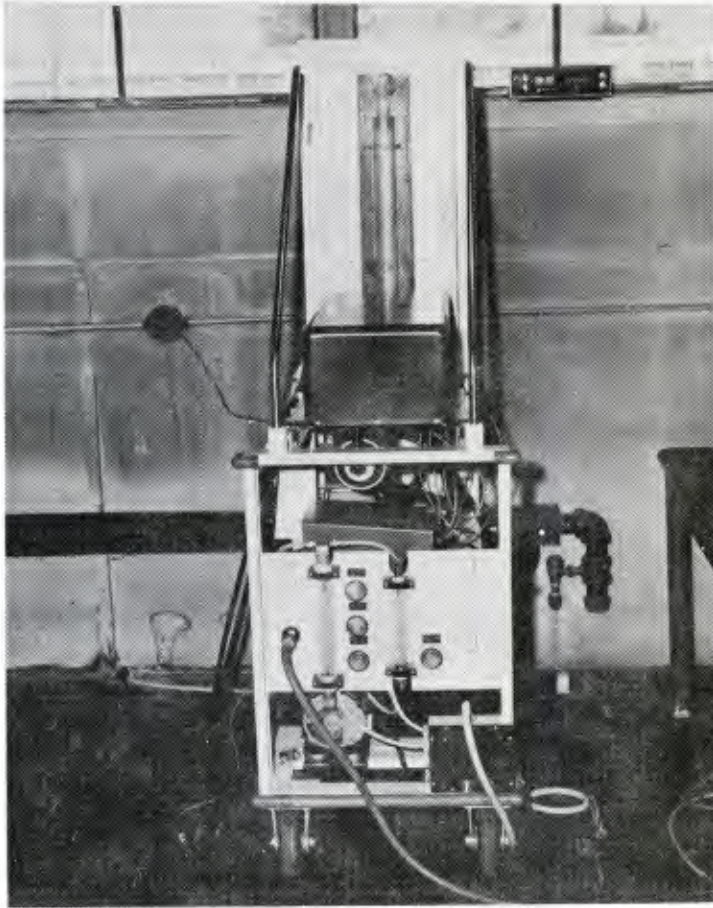


Figure 1 -

XQ127A1 Prototype Tester

IMPLEMENTATION

The tester is being used in conjunction with Q127 to perform production acceptance inspection for the purpose of establishing the tester's reliability. However, the implementation of this tester is questionable since Dioctyl Phthalate (DOP) is the chemical aerosol used to perform the Penetrometer Filter Test. DOP is now considered to be a suspected carcinogen. The Chemical System Laboratories' Research Division is evaluating the significance of the threat and is determining the feasibility of using a different chemical aerosol.

MORE INFORMATION

To obtain more information, ARRADCOM CSL contact J. M. Sattler, AV 584-3510 or Commercial (301) 671-3510.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 577 4211 titled, "Modernization of Process Control of Explosive Compositions," was completed by the US Army Armament Research and Development Command in March 1981 at a cost of \$427,000.

BACKGROUND

This project was a continuation of the effort to develop rapid, accurate instrumental process analyzers to measure control parameters during the processing and loading of ammunition items. During FY76, both a composition analyzer system and automatic level control system were designed and fabricated. The level control system designed and built in FY76 was successfully operated in the melt pour pilot plant and required no further efforts. In FY77, the composition analyzer was to be installed and tested in the ARRADCOM continuous melt pour pilot plant. In addition, efforts were initiated on the development of an improved impact tester to characterize the sensitivity of explosives. This would assure the continuing quality of explosives produced.

SUMMARY

The objectives of this project were to test and evaluate the composition analyzer system developed in FY76 and to improve the impact testing of explosives by automating the equipment for impact testing in order to obtain accurate and precise data for the accept/reject criterion.

For the composition analyzer, the explosive composition gauge and accessory equipment were shipped from Science Application, Inc. (SAI) and installed at ARRADCOM's Continuous Melt Pour Pilot Plant during May 1980. Calibration and acceptance tests were carried out with both a simulant (phosphoric acid/water mixtures) and RDX/TNT slurries. The gauge, although having high precision, had an accuracy only as good as the knowledge of RDX/TNT in the calibration slurry. The system was first calibrated on 60/40 and 40/60 RDX/TNT slurries in the Melt/Pour process facility with the microprocessor control/readout unit more than 600 feet away in the Control Room. During this test, a pumping time of about 1 1/2 hours was required to achieve a uniform 40/60 mix.

With the gauge calibrated, a shakedown test was carried out with the following RDX concentrations: 59.40% (59.39%); 36.5% (unmeasured); and 26.41% (26.65%). The values in the parentheses are from the grab-sample chemical analysis tests, and the others from material balance estimates. The corresponding RDX/TNT Concentration Sensor results were 59.7%, 38.2% and 27.6%. These results were finally

used for an improved calibration (because of failure to carry out chemical analyses on the 40/60 slurry used for the initial calibration), and, with the more accurate calibration, all points fell well within less than 1% of the "known" concentrations. The gauge achieved the required performance objective (precision of better than 1%).

The automated impact tester was designed and fabricated as illustrated in Figure 1. In the operation of the tester, a measured amount of explosive was automatically inserted between two stainless steel foil strips. The metal was fed from spools and passed between the anvil and hammer for testing. The hammer weights could be raised and were driven by air pressure. A pressure transducer monitored the air pressure. A position sensor, together with an oscillator/demodulator, differentiator, and a delay trigger voltmeter was used to monitor the velocity of the hammer. A microphone was mounted near the anvil to detect the impact explosion. Comparators and relays were used to set the air pressures. A programmable desktop computer/controller retrieved data and performed calculations.

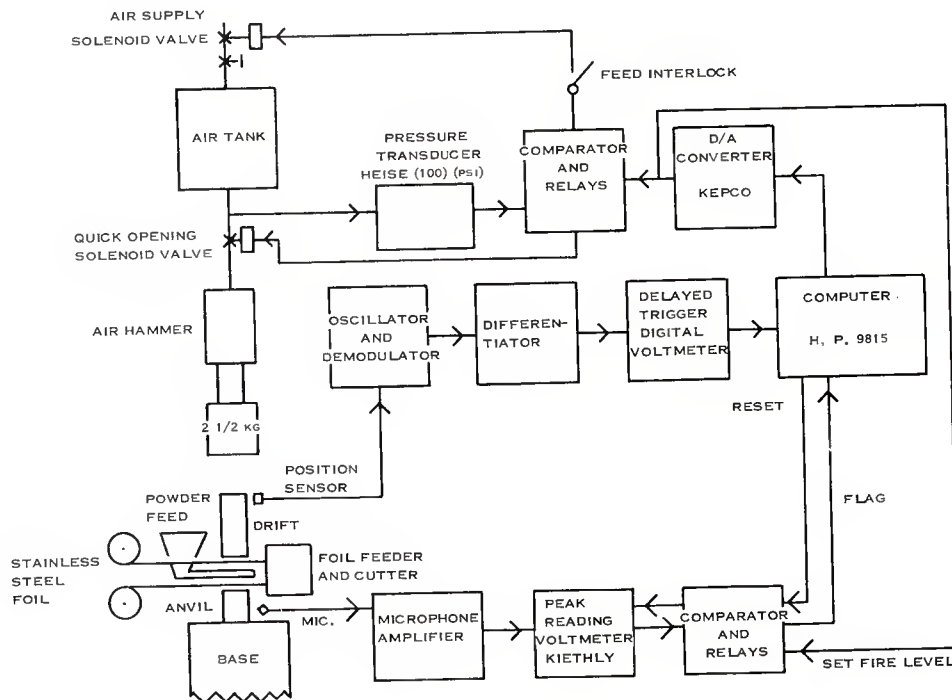


Figure 1 - Automated Impact Tester

In order to avoid possible electric arc initiation of explosives, the moving parts of the impacting system were activated by pneumatic controls. Furthermore, to insure safety in case of jams or improper functioning of individual parts, the entire impact testing procedure was sequentially controlled. Thus, in case of malfunction, the sequence ceased at the inoperative step and subsequent steps were not actuated.

Since the hammer was driven by air pressure, extensive runs were carried out to relate air pressure to impact velocity. Furthermore, since the computer controlled the air pressure and solenoid to drive the hammer, the relationship of digital input into the computer and the pressure buildup was determined. The interfacing of the controller/computer with the mechanical parts of the machine was accomplished and considerable effort was applied to debugging of the program.

Although the tester required additional work for complete automation, the equipment was tested in a semi-automatic manual mode. The results indicated satisfactory functioning of all mechanical parts and a complete impact test of 21 shots was completed in approximately 15 minutes.

BENEFITS

A composition analyzer system for determining RDX/TNT concentration was successfully developed and tested. Use of this system will result in improved process control and reduce operator exposure. In addition, an improved impact tester was developed which resulted in a more rapid and precise method for determining the sensitivity of explosives.

IMPLEMENTATION

The composition analyzer system for determining RDX/TNT concentration was installed in the ARRADCOM melt pour pilot plant and has potential application in the continuous Composition B line at Holston AAP. The implementation of the automated impact tester has been delayed pending required additional work.

MORE INFORMATION

Additional information may be obtained from Mr. C. McIntosh, ARRADCOM, AV 880-4123, or Commercial (201) 328-4123.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 6654 and 578 6654 titled, "Rapid Ultrasonic Inspection of Artillery Projectiles," was completed by the US Army Armament Research and Development Command in November 1980 at a cost of \$1,334,000.

BACKGROUND

Currently, the Army does not have a nondestructive test (NDT) system with the flaw detection and discrimination capability required to insure safety of the new high fragmentation artillery projectiles. The improved fragmentation steel properties are a compromise between toughness and brittleness. Therefore, it is essential that a highly reliable NDT system be developed to assure that stringent drop test requirements are met for the high fragmentation artillery projectile.

SUMMARY

The objective of this effort was to design, fabricate and evaluate an automated NDT prototype artillery projectile inspection system using electro-magnetic acoustic transducer (EMAT) to detect longitudinal and circumferential flaws. (EMAT is a non-contact electromagnetic transducer developed for exciting and detecting ultrasonic waves, Figure 1.) The results of this effort produced a partially successful EMAT prototype artillery projectile inspection system, Figure 2. The partial success is primarily due to system inability to detect circumferential flaws and the unacceptable sound to noise ratio. However, the system has demonstrated:

1. The capability to determine actual levels of defect in longitudinal locations in the warhead.
2. The capability to detect .020" deep by 1" long Electrical Discharged Machined notches in .400" thick projectiles.
3. That longitudinal flaws can be located while the projectile is being rotated at speeds up to 180 rpm.
4. That the longitudinal flaw inspection of the 155mm M549 Warhead can be performed at actual production rates of 45 seconds per warhead.

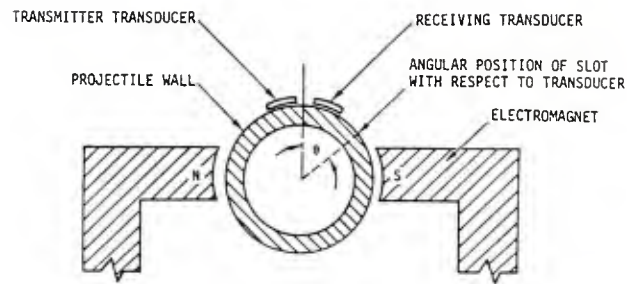


Figure 1 - Artillery Projectiles Inspection Apparatus Schematic

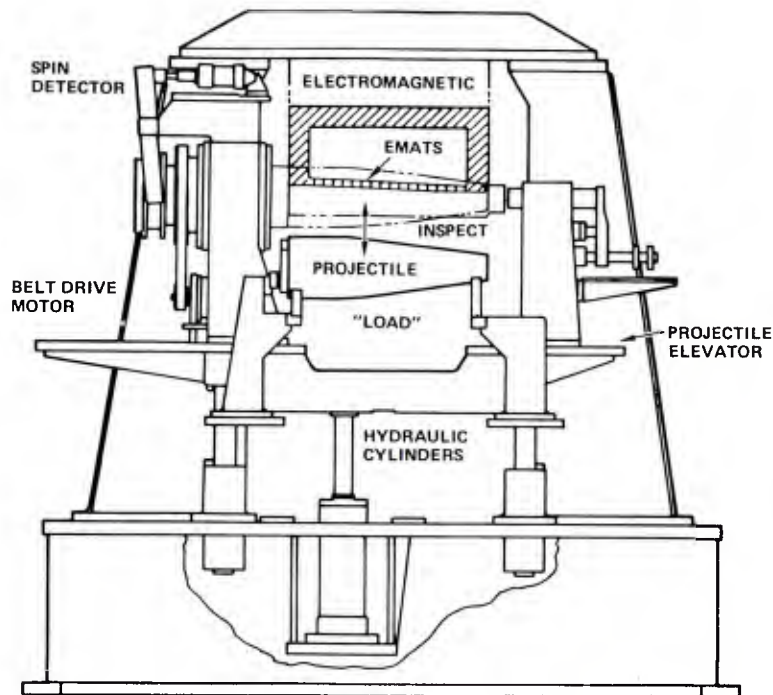


Figure 2 - EMAT Prototype Artillery Projectile Inspection System

BENEFITS

The potential benefits to be realized by the Army, once the circumferential flaw and sound-to-noise ratio problems have been corrected, are as follows:

1. Eliminate the subjective and redundant visual inspection of artillery projectiles at the metal parts and loading facilities.
2. The system will provide the capability to 100% NDT inspect high fragmentation artillery projectiles.
3. The system will reduce material and inspection labor costs.

IMPLEMENTATION

Until the circumferential flaw and sound-to-noise ratio problems have been corrected, the system will not be implemented. The ARRADCOM Product Assurance Directorate indicated that a MMT project will be initiated to correct the aforementioned problems.

MORE INFORMATION

For additional information, contact project officer J. Mulherin, ARRADCOM, AV 880-5751 or Commercial (201) 328-5751.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 674 7313, 676 7313, 677 7313 titled, "Simulator for Production Tests of Weapons," were completed by the US Army Armament Research and Development Command in January 1981 at costs of \$105,000, \$351,000 and \$205,000, respectively.

BACKGROUND

Traditional methods for the testing of automatic weapons have consisted of a go or no go function firing test under a single (and usually relatively rigid) mounting condition. In the field, the weapon encounters a wide variety of mounting conditions, some of which may cause malfunctions in certain weapons.

Many armament systems that have passed conventional acceptance test and/or production test requirements are found to possess inherent deficiencies when subjected to service requirements. In addition, no readily available means for the production testing of stabilized weapon systems exists.

SUMMARY

The objective of this program was to implement new testing techniques to assure that weapons and weapon systems meet field requirements. The approach was to build an active multi-degree-of-freedom hydraulic simulator capable of subjecting the weapon system during testing to the critical interactions that occur between the weapons and their service mounts or vehicles in the field.

An active six-degree-of-freedom simulator, Figure 1, capable of suspending sections of vehicles and allowing live firing of weapons was developed from an existing passive simulator. Characteristics of the simulator include:

1. Sophisticated mathematical models for simulating and programming spring rates and damping ratios.
2. A hydraulic power unit capable of providing a flow rate of 240 gpm at 3000 psi.
3. Simultaneous pitching of the simulator and the firing of the attached weapon.
4. Simultaneous yawing of systems attached to the simulator and the firing of the attached weapon.
5. A capability for applying vibration spectrums typical of those encountered in the field.

6. Automatic data acquisition and reduction.

A combat vehicle turret adapter for the suspension of turrets weighing up to 8000 pounds and a system to simulate tail rotor inertias was designed but, due to funding limitations, not fabricated.

BENEFITS

This program provided the Army with a unique facility for testing weapon systems, either mounted directly to the simulator or on portions of combat vehicles. The simulator is capable of simulating the flexibility of operational helicopters and lightweight combat turrets and is capable of withstanding the impulse loads of automatic weapons that are fired from vehicles mounted on the simulator. In addition, the requirements for a portable simulator capable of suspending smaller turrets for testing weapons at contractor plants were developed.

IMPLEMENTATION

The simulator has been applied to a number of Army Armament Systems, the most significant being the Advanced Attack Helicopter (AAH). Results from the testing were used to select the 30MM weapon which will be installed on the AAH. In January 1981, the simulator was used to determine the critical interactions between a 20MM weapon and the OH58Z Helicopter. This testing was conducted prior to flight testing thus reducing the risk inherent in mounting a high impulse gun on a lightweight helicopter.

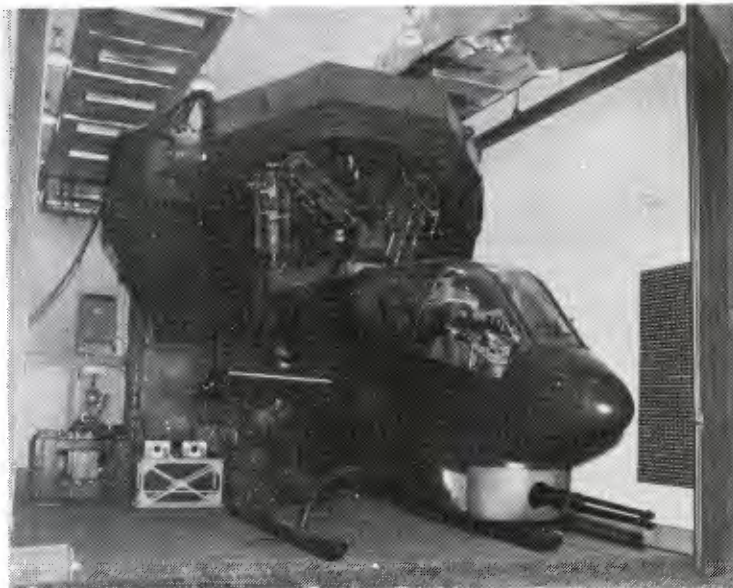


Figure 1 - Cobra Helicopter Mounted on DOF Simulator

MORE INFORMATION

The 6-DOF simulator is available to all DOD organizations for testing purposes. For additional information and a copy of the first report, contact Mr. Robert J. Radkiewicz, ARRADCOM, AV 793-6868 or Commercial (309) 794-6868.

Summary Report was prepared by J. H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 675 7589 titled, "Automated Targeting Systems for Production Testing of Automatic Weapons and Ammunition," was completed by the US Army Armament Research and Development Command in January 1981 at a total cost of \$130,000.

BACKGROUND

The traditional method of manually measuring target positions of projectiles is at present too time consuming and costly. In recent years, some semi-automated techniques using galvanometer slide-wire devices have been introduced to accelerate the measuring process. Fully automated scoring devices using acoustic sensors as targeting aids have been developed for use with small caliber projectiles (up to 7.62mm) fired in relatively long (100 meter-plus) indoor ballistic ranges. When acoustic sensors are used in small indoor ranges, echoing occurs causing false triggering. Currently, there is only one commercial system capable of fulfilling the military's needs for targeting systems; but that system is being treated as a proprietary item of the company. All other systems need further development in overcoming echoing and meeting the challenge of protecting the sensor when medium caliber (up to 30mm) projectiles are fired through the sensitive area.

In a prior effort, an automatic targeting system was developed and a prototype built using light sensing diodes to track the projectile path. However, this idea was abandoned because the system could not be adapted practically for large area scoring.

SUMMARY

The objective of this project was to select, purchase, install, and check out an electronic target scoring device using developed scientific principles without drastically modifying existing commercial equipment.

The scoring device selected and installed was an Accubar Model ATS-16D using the underlying physics principle of acoustic shock wave propagation. This principle has been used for several years in determining the x-y coordinates of supersonic projectile impact points. However, a theoretical restriction is that the axis of fire has to be perpendicular to the plane of the target area. To alleviate a potential design problem, a dual rod concept using acoustic sensors was developed. In addition, work was performed to develop an algorithm for measuring impact points and computing velocity of the projectile. The automatic target scoring device is a part of the entire system which consists of PDP-8E Minicomputer, and M1709 Interface.

This system has been specifically designed and developed for use in firing tests wherein the flight path of the projectile isn't required to be perpendicular to the target plane. To accomplish this, the system features a unique coplanar arrangement of rods; two are mounted vertically and two horizontally with a sensor attached to the edges, allowing the scoring points in each axis to be triangulated to the actual impact point on the target. The sensor rods, when mounted as previously mentioned, detect the ballistic shock wave which causes an electrical pulse to be generated by piezoelectric transducers located at the rod ends. These pulses are processed within the system, Figure 1, and the relative position of the projectile is automatically computed.

SIGNAL CONDITIONERS

X-AXIS FRAME ASSEMBLY

Dual Rod-sensor
Assembly,
with
Baffles

Target
Position

MAIN CABLES

Dual Rod-sensor
Assembly, with
Baffles

Y-AXIS FRAME ASSEMBLY

To Remote Control
(Computer)

CONTROL UNIT

To "Counter Start"
Generator

Gun Position

Figure 1 - Automatic Target Scoring System

BENEFITS

The system, when fully utilized, will be extremely efficient, accurate, versatile, and capable of scoring small caliber targets automatically with minimal range treatment. Also, when coupled with a computer, the system can produce additional statistical parameters other than impact points (e.g. extreme horizontal/vertical points, extreme spread, and various standard deviations, etc.). However, burst firing of 20mm and 30mm cannot be done without treating walls and floors with a material that will absorb and/or break-up the reflected shock waves.

The system with its present capability (without range treatment for burst firing of 20mm and 30mm ammunition) could reduce cost by \$15,000 per annum. When the full capability of the targeting system is realized, i.e., burst firing of 20mm and 30mm ammunition is possible, and the system is interfaced with the computer, cost savings of \$35,000 per annum are anticipated at the Ware Center, Rock Island, IL.

Some intangible benefits are listed below:

1. The system provides a firing interrupt signal and shuts off weapon firing as impact points approach the outer edges of the sand butt; this feature enhances the capability of six-degree-of-freedom simulator.

2. The maximum feasible burst length using color-coded ammunition and paper targets is normally 20 rounds; however, with the acoustic system, this capability is increased 250% to 50 rounds.

IMPLEMENTATION

The automatic targeting system will be used when the following conditions are met:

1. Test programs specify accuracy data on 5.56mm or 7.62mm weapons.
2. Modifications of firing range are completed to allow burst firing of 20mm and 30mm ammunition.

When these conditions are met, along with proper component interfacing, the standard operating procedure will be updated. At that time, the targeting system will become an integral part of the overall test philosophy at the Ware Center, Rock Island, IL.

MORE INFORMATION

Additional information on this effort is available in a technical report titled, "Automated Targeting System for Production Testing of Automatic Weapons and Ammunition," 1 January 1981, Donald E. Frericks, US Army Armament Research and Development Command, Rock Island, Arsenal, IL, 61299, AV 793-6868 or Commercial (309) 794-6868.

Summary Report was prepared by T. Locke, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project M77 6350 - 2028 titled, "Gun Tube Profile Inspection System," was completed by Watervliet Arsenal in April 1980 at a cost of \$60,000.

BACKGROUND

Gun tube chambers consist of various intersecting tapered and cylindrical areas. It is critical that these dimensions be accurate as out of tolerance dimensions cause lack of obturation, difficulties with chambering the ammunition and/or difficulties with case extraction. The reliability of the present chamber profile measurement techniques do not assure the required quality.

SUMMARY

The objective of this effort was to design and develop a reliable universal automatic gun tube chamber profile measuring system for the 105mm M68, 105mm XM205, and 105mm M137. The results of this effort produced a Gun Tube Chamber Profile Inspection System, Figure 1.

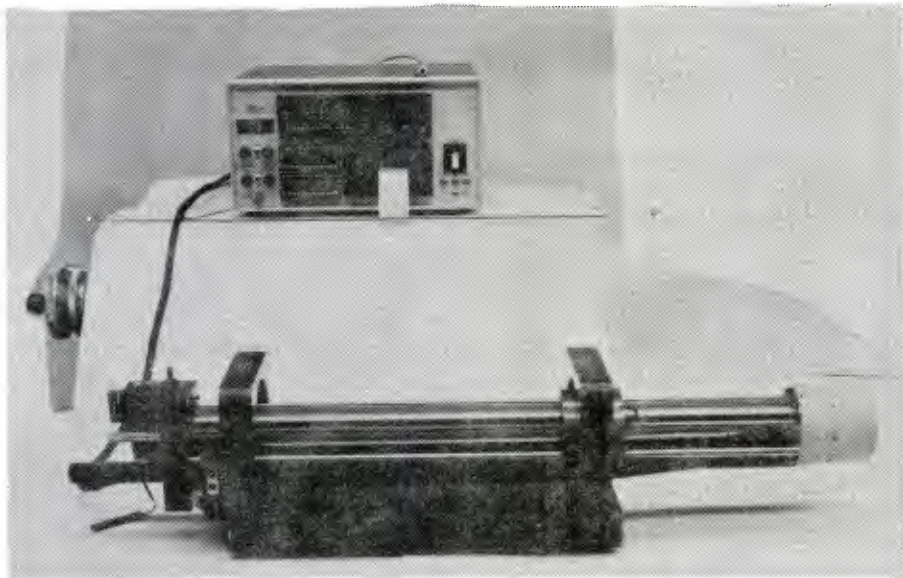


Figure 1 - Gun Tube Chamber Profile Inspection System

The system consists of two units, an electronic control, data processing console and a Cannon Chamber Gage. The chamber gage contains a master tool steel template scaled 1:1 to longitudinal cross section profile. Two radially opposed position sensors (LVDT's) measure the difference in a cross sectional diametrical plane between the master template and the chamber being inspected. A linear scale senses the down chamber location of the position sensors with respect to the rear face of the tube. The linear scale consists of a glass incremental grating scale and a traveling head. The reading head transmits light from a miniature filament lamp through the optical grating scale to two pair of photo detectors on the opposite side. As the head moves, it generates two signals, each of which is a close approximation of a sine wave. One signal train is displaced 90° in phase with respect to the other. This permits detection of direction of travel. The electronic control, data processing console presents a continuous display of the output of each LVDT with .0001 inch resolution. All displays are independently switchable from customary units (inches) to metric units. The continuous display of downbore distance has .0001 inch resolution. The displayed LVDT values and the downbore distance values can be printed upon command.

BENEFITS

The primary benefit realized by the Army from this effort is the capability to perform accurate gun tube chamber profile measurements which assure greater product quality.

IMPLEMENTATION

This system is in the process of being implemented on the 105mm M68 Gun Tube production line at Watervliet Arsenal, Watervliet, NY.

MORE INFORMATION

For additional information, contact the project officer, S. Krupski, Watervliet Arsenal, AV 974-5697 or Commercial (518) 266-5697.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project M77 6350-2032 titled, "Infrared Testing of Printed Circuit Boards," was completed in July 1978 by the US Army Missile Command at a cost of \$140,000.

BACKGROUND

Currently, printed circuit boards (PCB's) are tested for the presence or absence of specific electrical signals at specified locations within the circuits. Many flaws, poor solder joints, marginal components, electrical overloads, circuit imbalances, and neglected or improper heat sinking are conditions that may degrade the performance of the circuit board even though signals are within specifications. Damage to printed circuit boards occurs when operating temperatures become excessively high leading to pulling, peeling, or blistering of the copper conductor paths resulting in structural and electrical flaws.

SUMMARY

The objective of this effort was to design and develop a testing capability to identify and isolate PCB flaws. The results of this effort produced an inspection system that uses infrared sensing and scanning techniques to locate these abnormalities, see Figure 1. This system produces a thermal map of the printed circuit board during normal operation and a comparison of the thermal operation characteristics of the board under test is made with a prerecorded standard. The locations of faults are then read out by a computer.

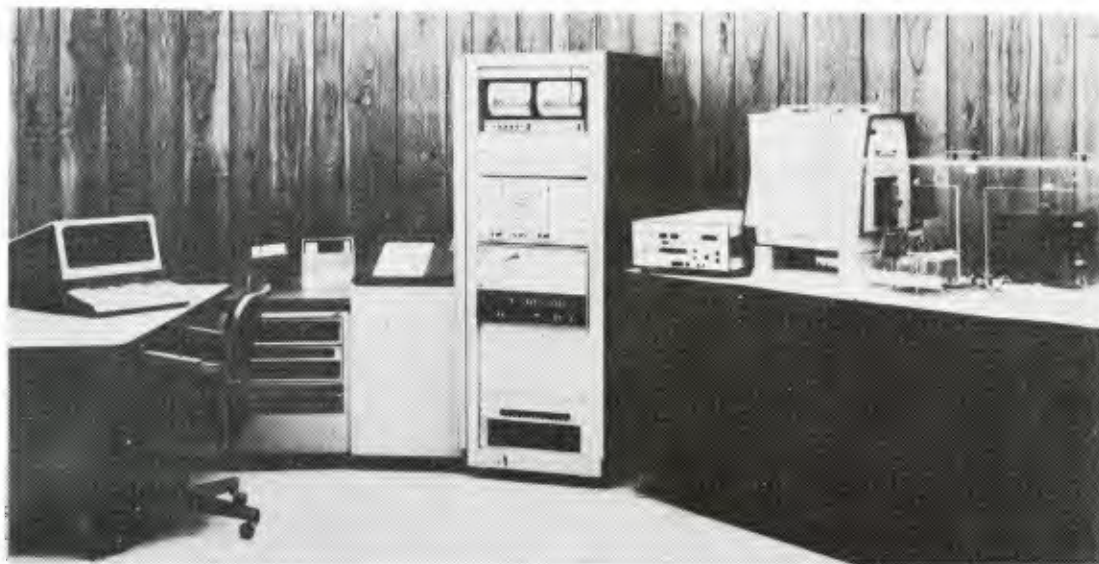


Figure 1 - Infrared System For Testing Printed Wiring Boards

BENEFITS

The results obtained from this effort demonstrated that the infrared sensing and scanning technique can be used to identify and isolate PCB flaws which are undetectable by existing techniques.

IMPLEMENTATION

The results of this effort were used to develop a full-scale production infrared inspection system under a follow-on MMT project, R78 3075. The full-scale production system developed has been used for evaluating PCB's for a number of Army Weapons Systems such as TOW Missile and M60A3 Tank. Hughes Aircraft Company, the developing contractor, is currently marketing this system commercially. A final technical report, E-79-10, titled, "Infrared Testing of Printed Circuits," dated 15 December 1978, has been published.

MORE INFORMATION

For additional information, contact the project officer, G. D. Little, MICOM, AV 746-3848 or Commercial (205) 876-3848.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

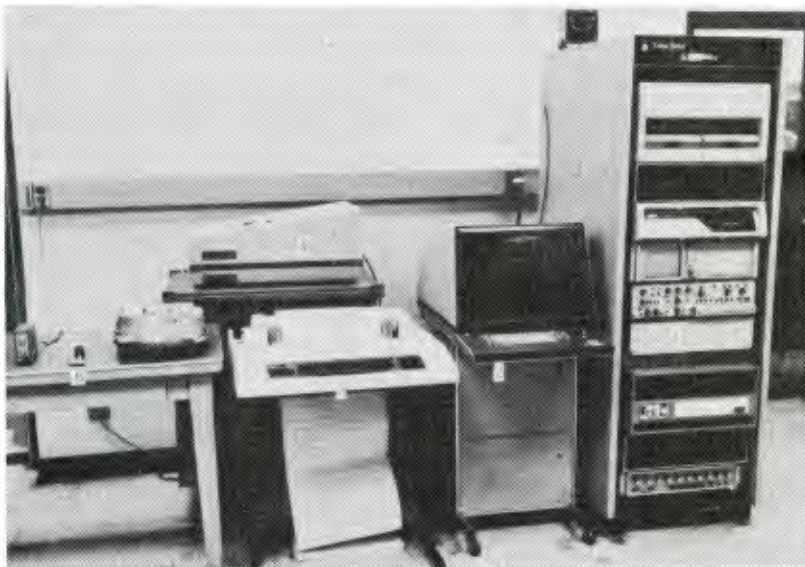
Manufacturing Methods and Technology project M77 6350-2037, titled "Computerized Modal Testing Methods for Air Defense Missile Fuzes," was completed by the US Army Harry Diamond Laboratory in May 1979 at a cost of \$69,500.

BACKGROUND

The Army air defense missile fuze acceptance Military Standards, MIL-STDS 810 and 331, require that all resonant vibration modes be identified. Current field condition resonant vibration are simulated manually using a modal technique. These manual modal tests are extremely complex which often produce unreliable results particularly when sharp vibration modes are required such as for the PATRIOT missile.

SUMMARY

The objective of this effort was to design, develop and test a computerized modal testing technique utilizing a digital mini-computer with on-line monitoring capabilities, Figure 1. The results of this effort produced a computerized modal tester. This tester has the capability to simulate known field vibration and evaluate the vibration modes (5 - 10,000 Hz range), and dynamic behavior of the fuze specimen. Also, this tester has the capability to automatically correct frequencies which insures dwell resonant frequency for a specified duration.



1. Data Acquisition and Analysis System
2. Command & Display Console
3. Teletype Printer
4. Hard Copy Unit
5. Patriot Fuze Mockup & Response Transducer
6. Excitation/Impulse Hammer
7. Hammer Signal Conditioner

Figure 1 - Computerized Modal Testing Equipment

BENEFITS

The potential benefits to be realized from this effort is that the Army will have the capability to field more reliable, accurate missile fuzes at a lower cost.

IMPLEMENTATION

This test equipment has been used by Harry Diamond Laboratories to establish the computerized modal test procedures for the PATRIOT fuze. This tester will be demonstrated to the PATRIOT and MLRS project offices for production acceptance test applications.

MORE INFORMATION

For additional information contact project officer, A. Frydman, HDL, AV 290-2937 or Commercial (202) 394-2937.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project R78 3440 titled, "Production Testing of Control Systems for Guided Weapons," was completed by the US Army Missile Command in January 1981 at a cost of \$547,000.

BACKGROUND

Guided weapons use gas operated control actuation systems (CAS) to control altitude and trajectory. The current single and four axis CAS production performance verification testing (PPVT) methods require manual setup and data collection. This method is very labor intensive and expensive. The average CAS PPVT requires approximately 75 minutes/guided weapon.

SUMMARY

The objective of this effort was to design, fabricate and test an automated CAS production performance verification test station. The results of this effort produced a modular automatic test station, Figure 1. This test station has the capability to perform the following PPVT tests: shaft lock backlash; potentiometer null; shaft rotation and phasing; stall torque; angular rate; position gain; frequency response; step response; duration/duty cycle; shaft lock activation and cutter resistance.

This test station consists of a main console and two test beds, one for COPPERHEAD and the other for the Navy's 5" system. An Intel iSBC 80/30 computer with 64K of memory resides in the main console which controls both test beds.

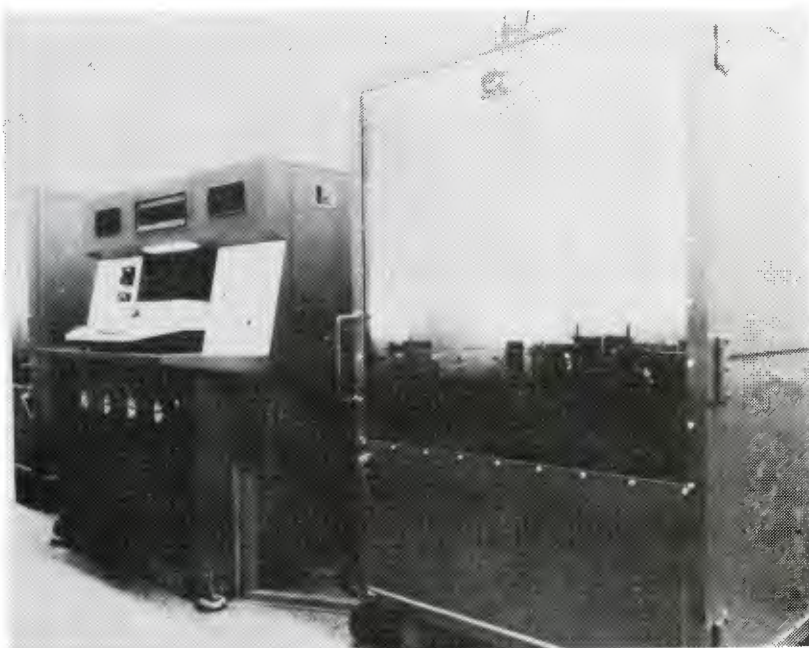


Figure 1 - Modular Automatic Test Station

BENEFITS

The use of the automated CAS PPVT test station has reduced inspection time to 10 minutes per guided weapon. This represents approximately 87 percent reduction in testing time. Also, the use of the test station has increased the inspection reliability by eliminating the human element. The substantially increased probability of detecting critical defects will reflect directly on increased field reliability.

IMPLEMENTATION

The CAS PPVT automated test station is being used by Chandler Evans, West Hartford, CN, 06101, to test the COPPERHEAD and Navy's 5-inch system production items. A contract has been awarded to procure a second CAS PPVT automated test station identical to the one developed by this effort. The second unit will have a command positioning and accuracy feature that will replace approximately \$200,000 of other test equipment.

MORE INFORMATION

Additional information concerning this project may be obtained from J. Byrd, AV 746-5563 or Commercial (205) 876-5638.

Summary Report was prepared by Delmar Brim, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

METALS



TWO-HIT FORGING PROCESS

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 175 7054 and 176 7054 titled, "Diffusion Bonded Titanium Spar Fabrication," were completed by US Army Aviation Systems R&D Command in November 1978 at costs of \$275,000 and \$195,000, respectively.

BACKGROUND

Plasma arc welding was originally selected by Sikorsky as a low-risk solution for joining the seam in the titanium blade spar on the YUH-60A, UTTAS prototype aircraft subsequently identified as the UH-60A, BLACK HAWK. This selection was based on information and experience available in 1971 when the aircraft was in its initial stage of design. Looking forward to future production requirements, several early manufacturing methods and technology programs were initiated and successfully completed. These early programs successfully evaluated continuous seam diffusion bonding as a potential lower cost, reliable alternate to plasma arc welding.

SUMMARY

The overall objective of this program was to implement the use of continuous seam diffusion bonding for the fabrication of helicopter main rotor blade spars. The program was planned as a production-oriented task with an integrated two-phase effort. Phase I was planned as a relatively low cost, risk reducing stage to establish the titanium sheet pre-form, process parameters, tooling, non-destructive inspection techniques, and physical testing procedures. Phase II was to scale-up the tooling and equipment to accommodate fabrication of full-size, 25-foot prototype spar tubes. Subsequent inspection and fatigue testing was to provide the necessary data base to determine the production cost for implementation of continuous seam diffusion bonding BLACK HAWK spars into production.

This program investigated and fabricated various shaped spar pre-forms and manufacturing operations that could be easily cold-brake formed from flat titanium sheet material. These were then continuous seam diffusion bonded and, subsequently, creep formed to the final contour. Tooling, which was capable of clamping and satisfactorily bonding the selected pre-form shape, was designed and constructed. Figure 1 depicts the continuous seam diffusion bonding (CSDB) concept used.

Process parameters relating to bonding variables and material conditions were evaluated. Three, ten-foot BLACK HAWK spar tubes were successfully diffusion bonded and non-destructively inspected. Finally, the fatigue characteristics of the diffusion bonded spar design were evaluated by full-scale and small-scale specimen fatigue testing. The process was found to be a technically feasible manufacturing method which could be used as an alternate fabrication procedure for blade spars, as well as other similar joining applications on Ti-6Al-4V aircraft structures.

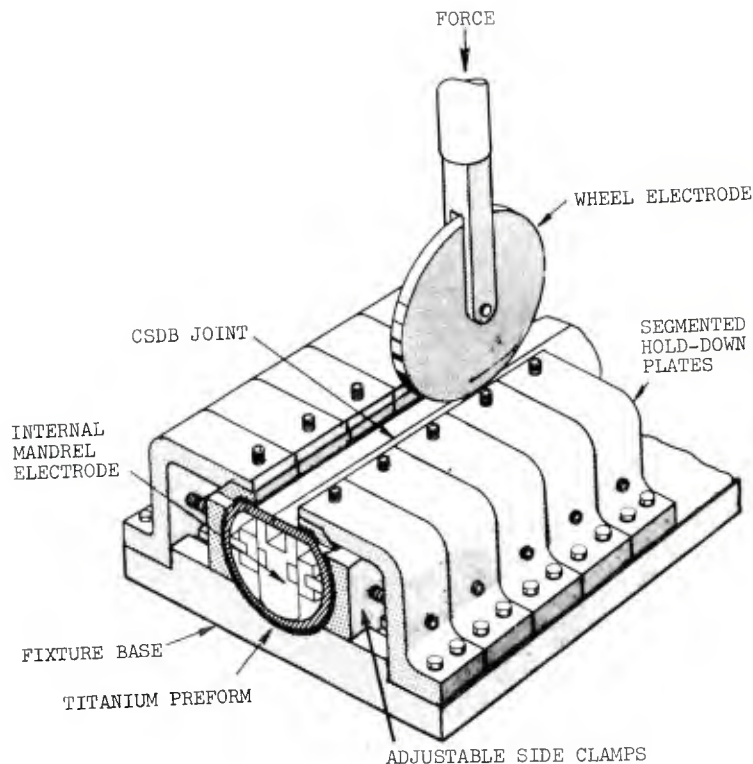


Figure 1 - Continuous Seam Diffusion Bonding Spar Concept

Although the results of this effort were technically successful, the application of CSDB spars in the UH60A helicopter were not recommended for the following reasons:

- (a) A substantial capital investment was already committed to production plasma arc welding equipment and a significant amount of full-scale qualification data on plasma arc welded spars had been obtained for the BLACK HAWK, UH60A helicopter.
- (b) A significant additional dollar commitment would still be required to scale-up the CSDB process to produce full-scale, twenty-five foot long production spars and to obtain the necessary qualification data.
- (c) The existing production schedule for the UH60A helicopter and the time at which CSDB spar implementation could be accomplished, would not yield a satisfactory return on investment.

BENEFITS

This project developed technology for the continuous seam diffusion bonding of titanium formed sheet into titanium hollow forms. These hollow forms were amenable to subsequent creep forging operations.

IMPLEMENTATION

Due to the reasons previously stated, and particularly since the advent of the all-composite blade, the technology developed for the CSDB spar was not used in that application. The technology is still available for implementation in other applications where hollow titanium shapes are required.

MORE INFORMATION

Additional information may be obtained by contacting Mr. A. Ayvasian at AMMRC, AV 955-3233 or Commercial (617) 923-3233.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 176 7114 and 177 7114 titled, "Improved Manufacturing Techniques for Infrared Suppression Aircraft Components," were completed by the US Army Aviation Research and Development Command in June 1980 and December 1980, respectively, at a total cost of \$343,000.

BACKGROUND

Current infrared (IR) suppression systems are expensive, heavy, reduce engine power available to the rotors, and increase the specific fuel consumption of turbine engines. Newly developed IR suppression systems are lighter, require less engine power, use less fuel, require less maintenance, and can fit a variety of engines. The newly developed IR suppression devices require manufacturing methods and technology development, such as low and high temperature brazing techniques for cooling fins, forming of finned ducts and elbows, manufacturing and bonding of duct metal insulation blankets, and forming of brazed structures to complex geometric shapes. The purpose of these projects was to establish manufacturing methods and techniques for cost effective production of IR suppression systems for turbine engines.

SUMMARY

This effort was conducted to investigate fabrication techniques and to optimize the manufacturing methods required for cost effective production of IR suppression devices for application to the AAH, UTTAS, AH-1, and CH-47 aircraft.

A survey was made of all electroform operations as used by industry. From this survey, it was determined how to design and fabricate the tooling, how to approach the actual forming operation, and how to design follow-on experiments. An electroshape die was cast out of kirksite and machined and polished to tolerance. Electroshape forming tests were conducted using aluminum, and 321 and A-286 stainless steels. It was found that vacuum was a very critical parameter in the process. Without close vacuum control, air becomes trapped between the blank and the die causing localized wrinkling, burn throughs, and spring-back. Other critical parameters were sealing, blank holding fixture design, ram pressure, and the design of the deflector. Redesign of the forming equipment and additional forming tests were continued until all process parameters were optimized. The electroshape process produces no areas of stress concentration or localized thinning that could allow stress concentration. The spring-back was minimal and the parts closely conformed to the shape and size of the die. Thus, the repeatability of the process was excellent.

Additional work included performing louvre forming in A-286 stainless steel by the "rubber pad" forming technique to study crack formation. It was found that

a hole punched in A-286 for stress relief along the louvre opening must be deburred carefully to prevent the perimeter of the hole from cracking during the forming operation.

Plasma arc cutting was tested for the louvre openings. It was found to be inadequate due to the thinness of the metal used on the OV-1 IR suppressor, and the width of gap and the heat affected zone caused by plasma-arc cutting. Laser cutting the louvre openings proved to be economical in relation to both the actual costs involved and the resulting quality of the openings to be pressure formed into louvres. The edges resulting from the laser cuts were found to be relatively smooth and crack resistant.

Analysis of time and material costs experienced during these projects indicated that the most economical method for manufacturing the OV-1 IR suppressor from either 321 stainless steel or A-286 stainless steel material consists of; (a) spin forming the suppressor in two sections using a preformed cone and a separately rolled cylinder, (b) welding the two sections together, (c) machining to required uniform thickness, (d) laser cutting louvre openings, and (e) pressure forming louvres. The methods and technologies utilized in each step were selected in order to obtain the optimum material strength in the completed suppressor at the most economical cost.

BENEFITS

These projects established an improved manufacturing method for preparation of louvres used in the film-cooled IR Suppressor System for Army aircraft. The proposed system will result in more efficient aircraft, will require less maintenance, and is applicable to a variety of engines.

IMPLEMENTATION

The results of these projects will be provided to private industry and Government agencies who have interests in infrared suppression aircraft components. Implementation of the manufacturing process in the near future is not being contemplated.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. Joe Pratcher, AVRADCOM, AV 693-1625. Final report titled, "Economic Evaluation of Manufacturing Methods and Technology for Spin Forming and Laser Cutting," was published by Astronic Company, Pasadena, California.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 176 7156 and 180 7156 titled, "Ultrasonically Assisted Machining for Superalloys," were completed by the US Army Aviation Research and Development Command in October 1980 at costs of \$300,000 and \$55,000, respectively.

BACKGROUND

Many aircraft parts are made of metal alloys that are difficult to machine by conventional methods. Materials such as 6Al-4V titanium alloy, hardened 17-4 PH stainless steel and hardened 4340 and 9130 steel alloys have valuable properties such as high strength, high hardness and good fatigue resistance. However, high cutting forces are usually required and material removal rates are low when using these steels. Consequently, turning operations for these materials are slow and costly. In addition, such materials tend to stick to the cutting tools and edge buildup on the tool frequently produces an undesirable surface finish.

Laboratory investigations during the last 20 years have demonstrated significant benefits with ultrasonic machining in terms of increased rates of material removal, decreased cutting forces, reduced tool wear, elimination of tool chatter and altered surface finish. Most of this work involved the more readily machinable materials such as aluminum, carbon steel and austenitic stainless steel. Low power (up to 600 watts) prototype ultrasonic systems were developed and successfully used for such applications.

SUMMARY

The objective of this project was to evaluate the technological and economic benefits associated with the application of ultrasonic energy during turning operations on difficult-to-machine materials. An ultrasonic lathe cutting system was designed and constructed to meet this objective. It consisted of a tool post capable of performing single-point metal cutting on an existing 7-horsepower LeBlond engine and diemaker lathe and a frequency converter to supply the required high frequency ultrasonic energy to the tool post. The ultrasonic system consisted of an ultrasonic transducer to generate high frequency vibration and an acoustic coupling system to transmit vibratory energy to the tool holder and insert. Figure 1 shows the ultrasonic tool post mounted on the cross slide of the LeBlond engine lathe.

Ultrasonic cutting tests were conducted on 9310 low-carbon steel, 4340 medium-carbon steel, 17-4 PH stainless steel, ESR 4340 electroslag refined steel, three titanium-aluminum alloys, and refractaloy 26. Based on these cutting tests, the following conclusions were made:

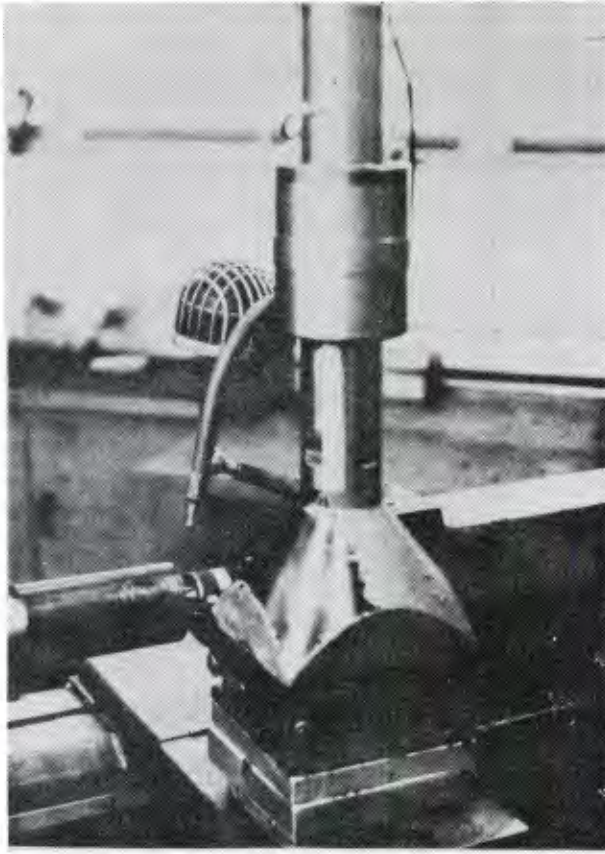


Figure 1 - Ultrasonic Tool Post Mounted on Cross Slide of the LeBlond Engine Lathe

1. Ultrasonically assisted machining greatly facilitates the turning of wrought metal alloys that are ordinarily difficult to machine, such as ESR 4340 steel, 9310 steel, 17-4 PH steel, several titanium alloys and refractaloy 26, increasing metal removal rates by as much as 700 percent.
2. Both cutting speed and cutting depth were increased over recommended standard cutting parameters.
3. Tool wear was significantly reduced with the use of ultrasonics; and tool breakage occurred less frequently with the use of ultrasonically assisted machining, indicating reduced tool loading.
4. Tool chatter was eliminated almost instantly when ultrasonic equipment was activated.
5. Ultrasonically assisted machining apparently has no consistent effect on surface roughness.

Upon completion of the cutting tests, the equipment was upgraded so that it could be installed on a 30-horsepower lathe.

BENEFITS

The execution of this effort has resulted in the development of ultrasonic machining equipment capable of functioning in a production environment. Additionally, it has been demonstrated that ultrasonically assisted machining greatly improves the metal removal rates obtainable on high hardness materials.

IMPLEMENTATION

The results of this effort have not been implemented to date. Plans are being made, however, to install the equipment at Corpus Christi Army Depot as soon as a suitable cutting lathe can be obtained.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Arthur Ayrazian, Army Materials and Mechanics Research Center, Watertown, MA, AV 955-3234 or Commercial (617) 923-3234.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 172 8041 and 173 8041 titled, "Precision Joining of Large Structural Components," were completed by the US Army Aviation Systems Command in March 1976 and September 1978 at costs of \$475,000 and \$360,000, respectively.

BACKGROUND

The use of titanium forgings for fatigue-loaded dynamic components has increased due to the continuing demand of the helicopter industry for increased performance. Some of these forgings are very large with intricate shapes. Typically, these components are machined from forgings which weigh significantly more than the finished part. These components include helicopter rotor hubs and D-shaped spars.

Solid-state diffusion bonding was identified as a manufacturing technique for fabricating large complex parts by joining separately forged details into one large component with intricate configuration. Solid-state diffusion bonding for titanium is achieved by heating the material significantly below its melting temperature and applying sufficient pressure over a period of time to produce a metallurgical bond superior to welding.

SUMMARY

The overall objectives of this program were to establish a diffusion bonding process for producing large, high strength, lightweight components for helicopters. The program was planned as a two-phased effort. The first phase was directed toward identifying the pertinent manufacturing process parameters for conventional rotor hub assemblies and examining the requirements for conversion to joined assemblies. The second phase selected the most likely component for cost reduction based on the joining process selected in the earlier work.

During Phase I, a contract was awarded to EF Industries to develop bonding parameters and tooling design for explosively bonding 6Al-4V titanium helicopter blade spar sections. This work was cancelled after it was learned that the process required more basic research before being considered for rotor spar production. Another contract was awarded to General Dynamics to establish nondestructive testing techniques (NDT) for diffusion bonded structures fabricated from Ti-6Al-4V sheets and forgings. Testing techniques developed by General Dynamics were later expanded by Sikorsky Aircraft. Sikorsky completed a program to establish the manufacturing methods and technology for forge-diffusion bonding an H-53 Helicopter Elastomeric Main Rotor Hub. A single arm of the H-53 rotor hub was actually selected as a risk reduction component. Although a full-size rotor hub was to be fabricated in this program, this phase was dropped. The process was shown not to be cost effective

for the full-size H-53 Elastomeric Rotor Hub. Figure 1 shows the forge-diffusion bonded program concept.

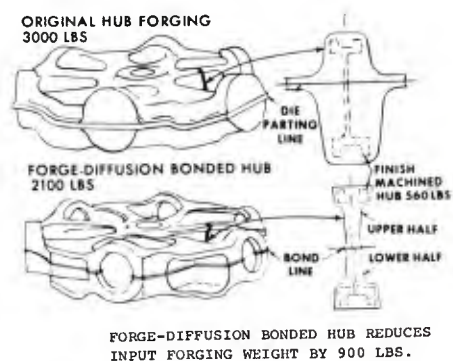
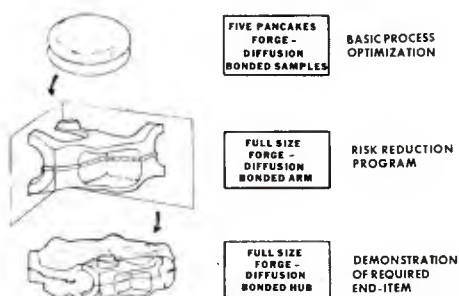


Figure 1 - Program Concept



Other joining processes such as plasma arc welding by Sikorsky Aircraft for producing titanium rotor spars, were attempted. This approach was cancelled in favor of developmental work in continuous seam diffusion bonding (CSDB). Successful efforts in CSDB led to initiating a program through Sikorsky Aircraft to establish a manufacturing capability to make spars from Ti6Al-4V sheet material. During the second phase of this program, areas investigated were: identification of the cause of joint failure along original sheet edge; a parametric study to determine controls required to achieve high quality diffusion bonded joints; identification of methods to repair defective joints; and applicability of various nondestructive inspection techniques. Results showed a wide range of bonding parameters over which parent metal properties were obtained.

As a result of this effort in CSDB, recommendations were made for a future program to apply this technology for the production of full size UH-60A Blackhawk (then UTTAS) Helicopter Rotor Spars. This work was carried forward in MMT projects 175 7054 and 176 7054 titled, "Diffusion Bonded Titanium Spar Fabrication."

BENEFITS

This project established the basic technology for the development of the manufacturing process of continuous seam diffusion for titanium sheet into hollow spar-like forms.

IMPLEMENTATION

Although this preliminary work led to a technically successful manufacturing process for producing CSDB spars in the Blackhawk Helicopter, the process was later found not to be cost and performance competitive with the all-composite rotor blade.

MORE INFORMATION

Additional information can be obtained from Mr. Arthur Ayvazian, AMMRC, AV 955-3233 or Commercial (617) 923-3233.

Summary Report was prepared by Ron Russell, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 374 3035 titled, "Processing Procedures for Adjacent and Intersecting Welds on Missile Components," was completed by the Army Materials and Mechanics Research Center for the Army Missile Command in December 1976 at a cost of \$87,000.

BACKGROUND

The welding of thin high-strength steel missile rocket cases often requires close proximity parallel and intersecting welds. Welding in close proximity to other weld joints creates concern for the fabricator and overwelding is often used to compensate for any negative weld properties. A redundancy of weld metal results, which may detract from performance and increase manufacturing costs. This problem is attributed to a lack of adequate welding specifications needed for the wide variety of thin sheet materials and configurations used in missile components. The need for improved welding techniques was encountered during the manufacture of the Hercules and Hawk Missiles.

SUMMARY

The objectives of this program were to determine the minimum weld buildup required for adjacent and intersecting welds and the effects that spacing between parallel welds might have on weldment properties. This project was the third and final phase of the effort for optimizing welding procedures for missiles and rockets. Joint geometries, surface preparation, heat treatment, and problems associated with both seam welds and combination seam and butt joints were investigated. For the study, thin sheets (0.032 to 0.063 inches) of AISI 4130, AISI 4340, and 18% nickel maraging steel were tungsten-arc welded with filler wire designated as Linde 70, Linde 140, Airco AX-140, and 18% nickel maraging steel. Data was gathered for parallel welds spaced 1/2, 3/4, 1, and 1 1/4 inches. Figure 1 shows representative photomicrographs of parallel welds with 1/2-inch spacing (Mag 5X).

A final report was provided at the end of the third phase. The conclusions were:

1. In welding high-strength steel alloys in relatively thin cross sections, it is mandatory that welding procedures be determined and maintained for producing sound welds.
2. Excessive buildup of weldments will not necessarily improve joint strength.
3. Minor variations in electrode configuration of wire feeding geometry, joint preparation and fixturing of the joint can greatly effect the weld quality.

4. Manual repair of weld faults in intersecting welds is not a feasible solution.

5. Mechanical properties of the weldment were not affected by minor changes in voltage, amperage, travel speed, and wire feed rate.

6. There are no interrelated effects between parallel welds down to 1/2-inch spacing.

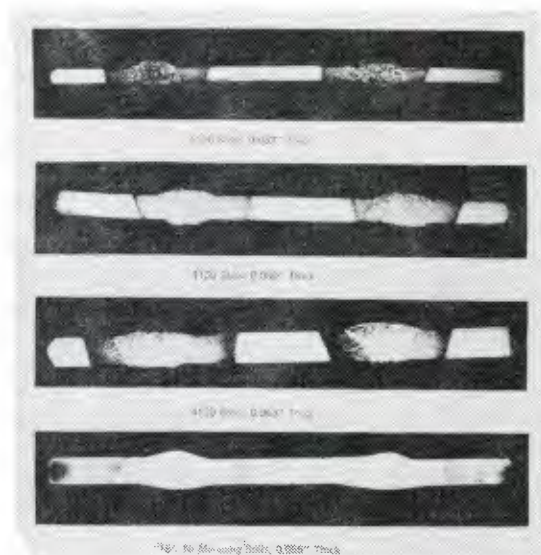


Figure 1 - Representative Photomicrographs of Parallel Welds - 1/2" Spacing. Mag. 5X

BENEFITS

This project established welding procedures for manufacturers involved with components fabricated from close proximity welds from relatively thin sheets of high-strength steel.

IMPLEMENTATION

The Technical Report No. AMMRC TR 7642 titled, "Parallel and Intersecting Welds in High-Strength Steel Sheet," was completed in December 1976 and distributed to Army, Navy, and Air Force Offices. Because no attempt was made to weld missile or rocket cases as originally planned, the implementation results were limited to the transfer of information.

MORE INFORMATION

Additional information may be obtained on this project from Mr. Dino Patetti, Army Materials and Mechanics Research Center, Watertown, MA, AV 955-3236 or Commercial (617) 923-3236.

Summary Report was prepared by Ron Russell, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 474 4329 and 475 4329 titled, "Joining of Steel Armor Intermix," were completed by US Army Tank-Automotive R&D Command in March 1979 at costs of \$132,000 and \$150,000 respectively.

BACKGROUND

This two-phase effort was initiated to provide methods for manufacturing steel armored vehicles with a higher level of ballistic protection than the level then provided - or to meet the existing protection levels with a reduction in weight. It was recognized that in either case, a better end item would result. The achievement of increased ballistic performance per unit weight entailed the use of new armor materials. These materials were much harder than conventional armor but were substantially more subject to cracking under the heat effects of flame cutting or welding.

The Phase I project 474 4329 developed the flame cutting procedures and explored the weld joint geometry and welding procedures.

SUMMARY

Project 475 4329 was the second and final phase of the program. Its purpose was to refine the methods which would be necessary to weld the large armor plate sizes being used.

During this investigation, several welding processes were used to deposit weld metal into full penetration joints in standard armor. The optimum process, or combination thereof determined by results of ballistic firing tests, was used to join armors of different types and hardnesses. The types were: (1) standard, (2) high hardness, and (3) Electro Slag Remelt (ESR). The combinations used were: standard to high hardness, standard to ESR, and ESR to high hardness. A mock hull was fabricated of these armors to determine their compatibility in a single structure. Radiographic inspection revealed the hull to be free of flaws. Figure 1 shows the mock hull being welded.

The combination of welding processes which produced the most consistent high quality weldments in the least time was that in which the root pass was deposited with a stick electrode and the remaining passes with the gas metal arc (MIG) process, either the standard or pulsed. Although all combinations of the three types of armors tested could be joined with the above welding procedure, ESR was dropped from consideration because of its erratic behavior and the poor ballistic results of the ESR combination with standard armor.

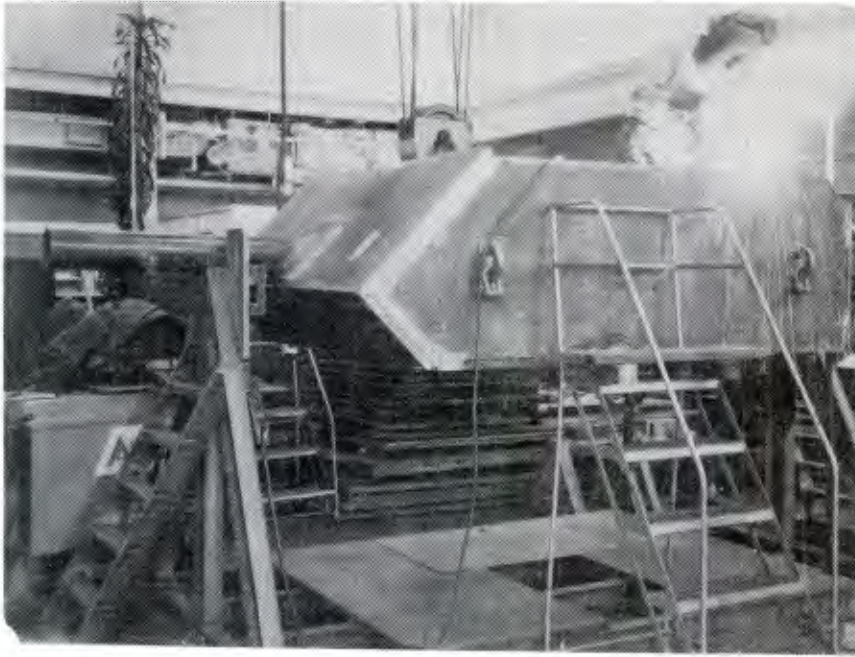


Figure 1 - Mock Hull
Being Welded

BENEFITS

This project developed production methods to join armors of different types and hardness and to utilize the new high performance armor materials. Higher levels of ballistic protection for combat vehicles can be achieved through their use.

IMPLEMENTATION

The armor welding specification MIL-SPEC-W46086 was revised to include the processes developed in this effort. Chrysler is using this specification and these processes for welding armor on the M1 Tank.

MORE INFORMATION

Additional information may be obtained by contacting Mr. B. A. Schevo, TARADCOM, at AV 273-1814 or Commercial (313) 573-1814.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 473 4335 titled, "Suspension Torsion Tube Springs," was completed by the US Army Tank-Automotive Command in June 1976 at a cost of \$401,000.

BACKGROUND

Torsion bars are currently manufactured from AISI 8660 steel and the torsion tubes from aircraft quality AISI 4340 steel. The fabrication method currently used to produce the torsion tubes is by machining either bored bar stock or seamless tubing. Up to 80 percent of the original stock is machined away, depending on the configuration of the starting material. Thus, a considerable quantity of expensive alloy steel is reduced to low-value scrap. In addition, machining does nothing to enhance the metallurgical quality of the material. A manufacturing technique is required which will reduce the scrap to a level of 2 to 5 percent while reducing production time and improving component durability and reliability.

SUMMARY

The objective of this project was to determine the most desirable manufacturing process for the mass production of suspension torsion tube springs with emphasis on unit cost, production rate, production functional characteristics, and product durability and reliability. Inertia welding, hot hydrafilm extrusion, and hot upsetting were the processes evaluated during this project. Cold forming was also identified as a possible process, but insufficient funds precluded contracting for test samples produced by this method. Twenty test samples were fabricated for each process with one process being evaluated by each of three contractors.

Battelle Columbus Laboratories evaluated the hot hydrafilm process. This process has the advantages of both hot and hydrostatic extrusion. Elevated temperatures reduce extrusion pressures, and a continuous and effective lubricant film lowers pressures even further, and gives excellent extruded surface finishes. The results of the extrusion trials demonstrated that the hydrafilm extrusion process can produce a net or near net internal configuration. Data also indicates that the process also improves fatigue properties as well as being more cost effective than by the process of machining from drawn tubing. See Table 1. Evaluation of other process parameters such as extrusion temperature and quench rate should be done by tensile and fatigue testing. It shows a need for more development as a technique before it would be applicable to a production environment.

Table 1 -

Relative Costs to Produce Torsion Tube Springs by Two Manufacturing Sequences

<u>Quantity Produced</u>	<u>Relative Cost Per Item Produced</u>				
	<u>1,000</u>	<u>5,000</u>	<u>10,000</u>	<u>20,000</u>	<u>30,000</u>
Machining from Drawn Tubing	1.00	1.00	1.00	1.00	1.00
Hydrafilm Extrusion Process	0.83	0.78	0.76	0.75	0.74

World Aerospace Corporation was under contract to investigate the inertia welding process. The process encompasses the joining of three parts; two ends and one center section. All three are tubing items with a minimum amount of material to be removed, rather than one heavy wall piece of tubing as previously required and used. This method requires 39 1/2 pounds of steel to process and finish a part weighing approximately 32 pounds. The heavy wall tubing method requires 80 pounds of tubing. In addition, the ability to maintain component concentricity and overall product length on a consistent basis once the necessary equipment and controls were set up was also shown.

The inertia welding process resulted in better, less expensive torsion tubes. The welds make an exceptionally strong bond at a minimum cost with a minimum amount of wasted material and time.

Chrysler Corporation investigated the hot upsetting process for fabrication of torsion tube springs. Hot upsetting improves the grain flow and adds substantially to the strength of the tube. The problem with this approach is the difficulty of holding the concentricity between the body and ends of the tube within satisfactory limits of the tolerances. The hot upset process has been shown to be a non-viable process with the current state-of-the-art in forging tolerances and techniques. More tube material is required than for straight machining from tube stock.

BENEFITS

The project was terminated before the cost analysis could be completed and the cost reductions identified. It was anticipated that cost savings would result in the areas of reduced scrap and time for fabrication, and a reduction of failure rates in vehicle application.

IMPLEMENTATION

Inertia welding is being used to fabricate the tube-over-bar suspension system for the LVPT-7 Marine Corp landing vehicle. The tube is being fabricated by the Food Machinery Corporation.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. Richard Siorek, TACOM, AV 786-2029 or Commercial (313) 573-2029. Technical reports published as a result of this project are listed below:

"Torsion Tube Study Program," TR 12031 Chrysler Corp., Defense Division, March 1975.

"Investigation of Fabrication of Torsion Tubes by Inertia Welding," TR 12038, World Aerospace Corp., April 1975.

"Development of an Improved Method for Production of Torsion-Tube Springs for Tracked Vehicles," TR 12032, Battelle Columbus Laboratories, March 1975.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 4055 titled, "Modern Fuze Surface Finish Production Processes and Equipment" was completed by the US Army Armament Research and Development Command in March 1978 at a cost of \$50,000.

BACKGROUND

It has been estimated that burr removal costs in the United States exceeds two billion dollars annually. This figure does not include costs related to rework, reinspection, retest, and reassembly. In the munitions area, even greater significance than the costs of removing burrs are delayed production schedules and munitions "duds" that can be caused by inadequate removal of burrs. While deburring is accepted as a necessary operation in the production of piece parts, it has been a low priority item that has received little attention. Universal industrial acceptance of deburring equipment or procedures has not been established.

SUMMARY

The objective of this project was to systematically investigate a broad range of modern surface finish control treatments and selected burr removal processes for fuzing devices. An engineering study was conducted to evaluate various types of production equipment and processes, the results of which are summarized in Tables 1 and 2.

The study also identified the following as requiring additional research: (1) burr prevention techniques, (2) burr measurement techniques, (3) definition of allowable edge conditions, (4) documentation of deburring process capabilities and (5) mathematical modeling of deburring processes.

BENEFITS

This project resulted in a design guide which compiled, summarized, and compared the major process parameters of numerous deburring techniques, and quantified the major factors used in selecting a deburring process.

IMPLEMENTATION

The technical report associated with this project has been distributed to the various technical directorates at the US Army Armament Research and Development Command.

DEBURRING PROCESS	MATERIALS USED	DEBURR MECHANISM	SIDE EFFECTS	TOOLING COSTS	CYCLE TIME PER		SECONDARY OPERATIONS REQUIRED	EQUIPMENT COSTS	HEALTH AND SAFETY CONSIDERATIONS	LIFE OF MATERIALS	MATERIAL COSTS	COMMENTS
					PART	LOT						
1. ABRASIVE JET DEBURRING	AL ₂ O ₃	ABRASION	MATTE FINISH	\$100	5 MIN		CLEANING	\$2 500 - 40 000	CONTROL OF AIRBORNE DUST	4 LB/HR	\$6/4 LB	USED ON STEELS
2. BARREL TUMBLING	AL ₂ O ₃ SiC PLASTICS	ABRASION & FATIGUE	RESIDUAL STRESS CHANGES. SOME MATERIAL IMPREGNATION	-0-		2-8 HRS	CLEANING	\$200 - 5 000	NONE WITH PROPER CHEMICALS	200# MEDIA OR COMPOUND 10,000 PARTS	\$50 PER LB	TYPICALLY LEAST EXPENSIVE OF ALL PROCESSES. MOST COMMONLY USED PROCESS
3. CHEMICAL DEBURRING	BUFFERED ACIDS	CHEMICAL ATTACK	POLISHING BRIGHTENING	-0-		5-30 MIN	PRE-CLEANING	\$1 500 - 20 000P	TYPICAL CHEMICAL AND FUME PRECAUTIONS			USED FOR THIN BURRS
4. CHEMICAL VIBRATORY DEBURRING	CuSO ₄	CHEMICAL REACTION PLUS ABRASION		-0-		10-20 MIN	CLEANING	\$100 - 8 000	NONE			USED FOR RAPID STOCK REMOVAL
5. CHLORINE GAS DEBURRING	CHLORINE GAS	CHEMICAL ATTACK	POLISHES	\$100 - 300			CLEANING	NOT AVAILABLE	CHLORINE MAY REQUIRE STRICT SAFETY PROCEDURES			LAB METHOD ONLY
6. ELECTROCHEMICAL DEBURRING	ANY SALT SOLUTIONS	ELECTROLYTIC DEPLATING	STRAY ETCHING	\$150 - 500	1 MIN		REMOVE FILM	\$8 000 - 35 000	TYPICAL ELECTRICAL, CHEMICAL AND GASEOUS PRECAUTIONS	100 GAL 500 PARTS	\$05 PER GALLON	USED ON HARD TO REACH BURRS
7. ELECTROCHEMICAL VIBRATORY DEBURRING	CAUSTIC OR PHOSPHORIC ACID GRAPHITE	ELECTROLYTIC DEPLATING PLUS ABRASION		-0-		1 MIN-1 HR	CLEANING	\$11 000				ONLY ONE INSTALLATION IN U.S.
8. ELECTROPOLISH DEBURRING	BUFFERED ACIDS	ELECTROLYTIC ACTION	POSSIBLE PITTING, STREAKING	\$200 - 500		1-10 MIN	PRE-CLEANING	\$1 500 - 25 000	TYPICAL ELECTRICAL, CHEMICAL AND GASEOUS PRECAUTIONS			USED ON THIN BURRS
9. EXTRUDE HONE DEBURRING	SILICONE PUTTY SiC AL ₂ O ₃	EROSION	POLISHES	\$100 - 500	1 MIN		AIR PLUS ULTRASONIC CLEANING	\$20 000 - 30 000	NONE WITH ADEQUATE HYDRAULIC PRESS CONSIDERATIONS	40 LB 10,000 PARTS	\$10-10/LB	USED ON HARD TO REACH BURRS
10. FLAME DEBURRING	H ₂ + O ₂ ACETYLENE	MELTING		-0-			CLEANING	\$150 - 1 500	COMBUSTIBLE GASES			TYPICALLY USED ONLY ON LARGE CASTINGS
11. HAND DEBURRING USING KNIVES, MOUNTED POINTS AND BRUSHES	STEEL KNIVES AL ₂ O ₃ SiC NYLON	CUTTING OR ABRASION		\$5 - 50	1-20 MIN		NONE	\$0 - 100	NONE			USED FOR PRECISION OR ON HARD TO REACH AREAS
12. HARPERIZING	AL ₂ O ₃	ABRASION	PRODUCES LARGE RESIDUAL COMPRESSIVE STRESSES	-0-		5-20 MIN	CLEANING	\$2 500 - 7 500	NONE	200# 5,000 PARTS	\$50	USED ON SMALL PARTS
13. LIQUID HONE DEBURRING	WATER SiC	EROSION		\$100 - 500	1-5 MIN		CLEANING	\$500 - 20 000	NONE		\$50/LB	USED ON THIN, SHORT BURRS
14. POWER BRUSHING	NYLON FIBERS AL ₂ O ₃ SST FIBERS	ABRASION OR CUTTING	POLISHES	\$0 - 200	1-5 MIN		CLEANING	\$50 - 15 000	NONE OTHER THAN FOR ROTATING WHEELS	1 BRUSH 10-1000 PARTS		USED ON ALL BURRS
15. POWER SANDING	SAND PAPER AL ₂ O ₃ SiC	ABRASION		\$0	1-5 MIN		CLEANING	\$100 - 2 000	NONE			USED ON FLAT PARTS
16. SPINDLE FINISHING	AL ₂ O ₃	ABRASION		-0-	1-5 MIN		CLEANING	\$7 500 - 11 000	NONE	200# 5,000 PARTS	> 50	USED ON LARGER PARTS
17. THERMAL SHOCK DEBURRING	H ₂ O ₂	MELTING PLUS SHOCK	COVERS PART WITH 'SMUT'	\$250 - 500		60-600 PARTS/HR	CLEANING	\$60 000 - 150 000	TYPICAL CONTROL OF COMBUSTIBLE GASES PLUS CONSIDERATION OF CONTROLLED DETONATIONS		\$05 PER PART	USED ON THIN BURRS ON COPPER ALLOY PARTS
18. ULTRASONIC DEBURRING	ACIDS BUFFERS	CHEMICAL ATTACK	POLISHING BRIGHTENING	-0-		5-10 MIN	NONE	\$1 500 - 15 000P	TYPICAL CHEMICAL AND FUME PRECAUTIONS			USED FOR THIN BURRS
19. VIBRATORY DEBURRING	AL ₂ O ₃ SiC PLASTICS	ABRASION & FATIGUE	RESIDUAL STRESS CHANGES. SOME MATERIAL IMPREGNATION	-0-		2 HRS	CLEANING	\$100 - 8 000	NONE	200# MEDIA OR COMPOUND 10,000 PARTS	\$50 PER LB	TYPICALLY LEAST EXPENSIVE OF ALL PROCESSES. MOST COMMONLY USED PROCESS
20. WATER JET DEBURRING	WATER	EROSION & CAVITATION	NONE	\$0 - 100	1 MIN		NONE	\$50 000 - 100 000	NONE			USED ONLY ON THIN OR BRITTLE BURRS

VALUES LISTED REPRESENT TYPICAL EFFECTS ON STEEL PIECE PARTS UNLESS OTHERWISE NOTED. VALUES ARE BASED ON A BURR THICKNESS OF 0.002, PARTS OF ONE CUBIC INCH OR SMALLER SIZE, AND BATCH SIZES OF 100 PARTS/MONTH. P INDICATES PROBABLY.

Table 1 - Major Factors in Selecting Deburring Processes

DEBURRING PROCESS	APPLICABLE TO THESE WORKPIECE MATERIALS	BURR SIZES TYPICALLY REMOVED*	EDGE RADIUS TYPICALLY PRODUCED** IN			EFFECT ON ADJACENT SURFACES	EFFECT ON PIECE PART SIZE*** IN	PIECE PART GEOMETRY LIMITATIONS	APPARENT BEST REPEATABILITY OF EDGE RADIUSING, IN			COMMENTS
			SST & STEEL	BeCu	Al				SST	BeCu	Al	
1. ABRASIVE JET DEBURRING	METALS, PLASTICS	.0005-.0050 THICK	.003-.010			MATTE FINISH IS PRODUCED	NONE	BURR MUST BE ACCESSIBLE TO ABRASIVE STREAM				
2. BARREL TUMBLING	ALL METALS AND PLASTICS	.0001-.003 THICK	.003-.010	.004-.010	.006-.030	NONE	0-.0005 SIZE CHANGE	EDGES MUST BE READILY EXPOSED. OTHERWISE WILL NOT DEBURR	+.0015	+.0025	+.0025	SELECT APPROPRIATE MEDIA AND COMPOUND IF WELDING OR PLATING FOLLOWS DEBURRING
3. CHEMICAL DEBURRING	IRON, STEELS STAINLESS STEELS, COPPER ALLOYS, BRASS, BRONZE, ALUMINUM	.0001-.0005 THICK				.000050 IN. PER MINUTE ETCH RATE ON HIGH CARBON STEEL	.000050 IN. PER MINUTE ETCH RATE ON HIGH CARBON STEEL					PART MUST BE CLEAN PRIOR TO DEBURRING
4. CHEMICAL VIBRATORY DEBURRING	STEEL ALLOYS						SOME STOCK REMOVAL	SAME AS VIBRATORY				SAME AS VIBRATORY
5. CHLORINE GAS DEBURRING	METALS	.0002-.002 THICK	.005-.020			.0004-.010 STOCK REMOVAL	.0004-.010 PER SIDE STOCK REMOVAL					LAB PROCESS ONLY AT THIS TIME
6. ELECTROCHEMICAL DEBURRING	ALL METALS	.0003-.003 THICK .001-.020 LENGTHS	.002-.010	.002-.010	.006-.030	SLIGHT ETCHING, 0-.010 STOCK REMOVAL	POSSIBLE STRAY ETCHING		+.002		+.004	NOT WELL SUITED TO ALUMINUM
7. ELECTROCHEMICAL VIBRATORY DEBURRING	METALS	.002-.005 THICK	.005 MAX			SOME ETCHING POSSIBLE	.0002-.0003 SIZE CHANGE TYPICAL	BURR MUST BE ACCESSIBLE BY GRAPHITE SPHERES	+.002			+. HOLES ARE ENLARGED .0002 IN ONE TEN-MINUTE CYCLE
8. ELECTROPOLISH DEBURRING	STAINLESS STEELS, HIGH TEMP METALS, ALUMINUM, BERYLLIUM	.0001-.0005 THICK	.001-.005		.001-.005	POLISHES, UP TO .0005 STOCK REMOVAL PER SIDE	UP TO .0005 STOCK REMOVAL PER SIDE		+.00005			
9. EXTRUDE NONE DEBURRING	ALL METALS MACHINED PLASTICS CERAMICS	.0002-.003 THICK	.001-.005		.002-.005	POLISHES, SLIGHT STOCK REMOVAL (ADJUSTABLE) 0-.004	NONE	BLIND FEATURES WILL NOT BE DEBURRED	+.0005	+.0005	+.001	UTILIZED ON HARD TO REACH INTERSECTIONS AND WHERE REPEATABILITY IS REQUIRED
10. FLAME DEBURRING	METALS PLASTICS											
11. HAND DEBURRING, USING KNIVES, MOUNTED POINTS AND BRUSHES	ALL MATERIALS	.0002-.003 THICK	.002-.010	.002-.010	.003-.015	NONE	NONE	BURR MUST BE ACCESSIBLE	+.002	+.002	+.003	CAN BE USED AS PRELIMINARY DEBURR TO REDUCE BURR SIZE FOR COMMERCIAL PROCESS
12. HARPERIZING	METALS, PLASTICS	.0002-.003 THICK	.003-.020	.003-.020	.005-.030	NONE	0-.0005 SIZE CHANGE	SAME AS VIBRATORY				SAME AS VIBRATORY
13. LIQUID NONE DEBURRING	METALS, PLASTICS	.0002-.001 THICK	.005 MAX				NONE	BLIND FEATURES WILL NOT BE DEBURRED				
14. POWER BRUSHING	METALS, PLASTICS	.0002-.002 THICK	.002-.010	.002-.010	.003-.015	POLISHES	NONE	LIMITED TO EXTERNAL BURRS IN MOST MINATURE APPLICATIONS	+.002	+.002	+.003	
15. POWER SANDING	METALS	.0002-.003 THICK				SCUFFED	.0003-.002 STOCK REMOVAL	LIMITED TO FLAT PARTS IN MOST CASES				CAN BE USED AS PRELIMINARY DEBURR
16. SPINDLE FINISHING	METALS, PLASTICS	.0002-.003 THICK	.001-.020	.003-.020	.005-.030	NONE	0-.0005 SIZE CHANGE	SAME AS VIBRATORY				SAME AS VIBRATORY
17. THERMAL SHOCK DEBURRING	METALS PLASTICS	.0002-.002 THICK	.002-.016		.002-.060	SURFACES ARE COVERED WITH AN OXIDE	.0001-.0005 SIZE CHANGE, SURFACES ARE COATED WITH AN OXIDE	NO BLIND CONDITIONS, BURR AREA MUST BE FREE FROM OILS AND WATER	+.003	+.003	+.005	CALLED SURFTRAN RECOMMENDED FOR CARBURETOR PARTS
18. ULTRASONIC DEBURRING	COPPER ALLOYS, BRASS, ZINC, ALUMINUM	.0001-.0005 THICK						SOME LIMITATIONS ON ROUND PARTS				
19. VIBRATORY DEBURRING	ALL METALS AND PLASTICS	.0001-.003 THICK	.003-.010	.004-.010	.006-.030	NONE	0-.0005 SIZE CHANGE	EDGES MUST BE READILY EXPOSED. OTHERWISE WILL NOT DEBURR	+.0015	+.0025	+.0025	SELECT APPROPRIATE MEDIA AND COMPOUND IF WELDING OR PLATING FOLLOWS DEBURRING
20. WATER JET DEBURRING	MOLDED ASBESTOS/ SISAL, ALUMINUM ALLOYS	0-.0015 THICK FLASH				CLEANS	NONE	LIMITED TO EXTERNAL BURRS/FLASH				UTILIZED BY AUTOMOTIVE INDUSTRY

*VALUES LISTED REPRESENT PRELIMINARY INFORMATION APPLICABLE TO PRECISION SMALL AND/OR MINATURE COMPONENTS

**IN A 2 HOUR DEBURRING CYCLE

***THESE VALUES ARE CONSERVATIVE FOR HAND SIZED PARTS OR LARGER

Table 2 - Comparison of Major Parameters of Deburring Processes

MORE INFORMATION

Additional information may be obtained by contacting Mr. Ray Goldstein, ARRADCOM, AV 880-2903 or Commercial (201) 328-2903.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 578 4148, titled "Reduced Weight Forging for the 8-Inch Motor Body, XM650," was completed by the US Army Armament R&D Command in January 1979 at a cost of \$79,000.

BACKGROUND

The original forging used in the production of the XM650 motor body weighed about 125 pounds and required extensive stock removal in the machining operations. It was believed that significant savings in material and operating costs could be achieved by developing a forging which was lighter in weight and more adaptable to high production rates. The objective of this project was, therefore, to produce a lighter weight forging in order to reduce the cost of the rocket motor.

SUMMARY

Effort was directed toward the development of a forging which would:

1. Be producible using standard commercial forging equipment.
2. Weigh 103 pounds.
3. Have sufficient excess material to clean-up to print with less stock removal than before.
4. Develop the required physical properties after conventional heat treatment.
5. Be processible on existing equipment with minimal changes to the tooling used to produce the R&D parts.
6. Be adaptable to high rate production.

The accomplishment of project objectives, within the stated criteria, involved a complete redesign of the forging and modification of the forging tooling. Sample forgings were then processed to finished parts for the validation of machining operations and the assurance of production rates.

After successfully producing the lightweight forging, all of its physical attributes were reviewed to assure that the new forging was equal to or better than the old forging. Various destructive and non-destructive tests were performed. After determining that the new forging was acceptable, approximately 400 rough forgings were made to prove reproducibility and determine tool wear characteristics. These forgings were subsequently used on contract DAAK10-79-C-0064.

BENEFITS

The development of a lightweight forging, weighing 20 pounds less than the forging previously used, was successful. The following specific advantages were derived:

1. Minimal changes to existing forging tools and dies, and a correspondingly minimal implementation cost.
2. Reduced amount of critical alloy steel used per forging.
3. Reduced machining time.
4. Reduced shipping and handling costs.

The material and labor savings discounted over a 5-year period were \$537,520. Savings in shipping and handling are unquantifiable.

IMPLEMENTATION

This technology was implemented in support of the 8" M650 RAP under contract DAAK10-79-C-0064.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Joseph Matura, ARRADCOM, at AV 880-2857 or Commercial (201) 328-2857.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 572 6358 and 573 6358 titled, "Investigation of Hot Parting Approach to Billet Separation," were completed by Frankford Arsenal in June 1976 at a cost of \$675,000 and \$101,000, respectively.

BACKGROUND

At the inception of this effort, the billet separation methods in use were nick and break, cold shear, flame cut, and saw. It appeared that these methods would suffer by comparison with the hot shearing method in the areas of material handling, material cost, operating cost, as well as product quality. The program objective was to establish whether the apparent advantages of hot billet parting could be realized in the production of projectile bodies.

SUMMARY

A hot shear press and associated tooling were purchased from Rheinstahl Wagner Co. in Dortmund, Germany. This press was delivered to the US and installed at National Presto Industries, Inc., Eau Claire, Wisconsin, to study the feasibility of the hot shear concept in the manufacture of projectiles. The hot shear concept of billet separation involves heating steel billet lengths (approximately 20 feet) to forging temperature, hot shearing to mult length, followed by immediate transfer to the forging press, and forging into a projectile. Using this concept, heating, separation and forging of the billet stock is an integrated, completely automatic operation.

After establishing optimum hot shear process parameters, a quantity of 100 multis were hot sheared at National Presto and subsequently forged into 105mm, M1 projectiles using Presto's standard hot cup-cold draw process. Visual and magnetic particle inspection were performed on each of these projectiles after forging and nosing operations. No defects were detected that could be related to the use of hot sheared multis. A significant finding of this study was that in terms of tolerance on length and weight and overall quality of the parted surface, hot sheared multis equaled or exceeded the results achieved using the band saw method of billet separation. Sawing, prior to this time, had been considered the most exact method, with the highest yield of any separation method.

By virtue of this study, the following advantages were attributed to the hot shear process:

1. Reduced material handling - All other separation methods are done cold. Therefore, individual mullets must be transported from the separation operation to the hot forge furnace, placed individually in the furnace, removed individually from the furnace and transported to the forge press. Hot shearing reduces material handling since the entire billet is heated to forging temperature, hot sheared to mult length and moved directly to the forging press in a completely integrated, synchronized, automatic operation.

2. Reduced material waste - The least desirable process in this regard is the nick and break process which is also the process most often used. Because of angular breaks, it is never certain what the weight of the broken mult will be. To compensate for this, mullets must be broken extra long to assure the mult will fill the die and produce an acceptable projectile. With both sawing and flame cutting, there is a kerf loss. Hot shearing eliminates waste by accurately separating to specified weight without kerf loss.

3. Reduced operating cost - High operating costs are associated with both the sawing and the flame cutting processes; sawing because of the saw blades and flame cutting because of gas and oxygen. Hot shearing operating costs will be relatively low. Up to 50,000 cuts per set of tooling is possible.

4. Reduced defective projectile cavities - Surface irregularities on the parted surface can cause quality problems in the finished projectile when using both the nick and break and flame cutting processes. The nick and break process leaves slivers of metal on the parted face which form laminations in the projectile cavity. If these defects are superficial, they are salvaged by hand grinding which is a costly operation. Flame cutting, when out of control, produces slag and surface irregularities. The hot shearing method has demonstrated that forged projectile cavities are as good as, or better than, cavities made by any other process.

5. Reduced scale - Scale is a problem associated with all of the existing parting processes. Mullets are parted before they are heated to forging temperature. During heating, all surfaces of the mullets are exposed to the furnace atmosphere and become scaled. Since one end of the mult becomes the inside surface of the projectile after forging, any scale present on the end of the mult becomes imbedded in the surface of the cavity. Hot shearing eliminates the scale problem since the end surface is cut after heating and is immediately forged.

Because of the potential benefits, the hot shearing process was recommended for implementation in any new facilities for projectile manufacture.

BENEFITS

A superior process was adapted to the manufacture of forged projectiles. Estimated cost advantages at project completion were \$0.34 each for the 105mm, M1 and \$0.51 each for the 155mm, M107.

IMPLEMENTATION

This technology is being implemented at Mississippi AAP in the manufacturing of the 155mm, M483 projectile body. At this writing, the equipment has been purchased and is awaiting installation.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Mohan Devareje at ARRCOM, AV 793-3204 or Commercial (309) 794-3204.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 574 6472 and 575 6472 titled, "Application of Alternate Processes for Fabrication of Precision Pinions Used in Mechanical Time Fuzes," were completed by the US Army Armament Research and Development Command in August 1976 at a cost of \$429,690 and \$200,000, respectively.

BACKGROUND

As a result of a fuze production base study conducted during 1971 and 1972, a shortage of mechanical time fuze precision components manufacturing capacity to meet mobilization requirements was identified. Specifically, the study pointed out that:

1. The available equipment for precision parts fabrication was obsolete.
2. The production base was dependent upon foreign sources for both the precision parts and the machine tools for manufacturing precision parts.
3. Critical skills for manufacturing precision parts were rapidly declining due to the loss of the precision parts manufacturing capability to foreign sources.

Two approaches embodying a number of directed actions were undertaken to provide solutions to these problems. The first approach was to implement those actions which would immediately improve the capability and reliability of the production base by directed allocation of procurement; eliminating imports of foreign precision parts and machine tools; and stockpiling of parts and equipment. The second approach was to conduct developmental and engineering programs to re-design the fuzes and establish alternate processes for the manufacture of precision components. A three-year MMT program was undertaken to accomplish the latter.

SUMMARY

The three-year effort was to be accomplished in three phases. The first phase was to produce fuze pinion and gears by several alternative processes. The second phase would assemble these gears into fuzes which would be tested. The best alternative process would then be selected and a pilot production line would be established to validate the mass producibility of the gears.

Four processes were selected for Phase I. They consisted of zinc die casting of gear and pinion assemblies using a modified involute tooth form in lieu of the cycloidal tooth form currently used; chemical etching of thin sheet material to produce wafer sections of the gear stacked and diffusion-bonded together to form the whole gear; conventional powder metallurgy process consisting of press and sinter operations; and hydrostatic extrusion of gear shaped stock which is screw machined and cut off to form the finished part.

Pinions were successfully produced by each process. Each process had disadvantages: zinc die casting, having been used to produce pinions in other fuzes, required the gear train to be modified to accept the modified involute gear tooth shape and the zinc material. These modifications raised questions as to suitability and reliability of the zinc die cast gears. Diffusion bonding the shaft to the chemically etched and stacked gear proved to be a problem in producing acceptable pinions. Stick and slip problems developed during hydrostatic extrusion resulting in a high reject rate. Machining problems occurred with the powder metallurgy gears. Turning tools chipped; the powder metal material chipped and flaked; pivots snapped off; and blank ends disintegrated.

A sample lot of fuzes was assembled from gears and pinions manufactured by each process. They were then environmentally and ballistically tested. The environmental tests consisted of jolt, jumble, forty-foot drop and transportation vibrations tests. The ballistic tests consisted of firing the assembled fuzes from a 105MM gun at zone 7 charge with a 60 second setting and a 155MM gun at zone 1 charge with a 3 second setting.

The test results revealed:

1. Zinc die cast gear and pinion assemblies appear structurally sound but functionally weak.
2. Chemical etching and diffusion bonding provided pinions that were successful in meeting test requirements.
3. Hydrostatic extrusion provided pinions that were successful in meeting test requirements.
4. Pinions produced by powder metallurgy were found marginal during environmental testing and, consequently, were not ballistically tested.

The third phase of the program, an FY76 follow-on project, has been funded to solve the stick, slip problem encountered in hydrostatic extrusion and to demonstrate the mass producibility of this process. Figure 1 shows samples of pinion-shaped bar produced by hydrostatic extrusion.

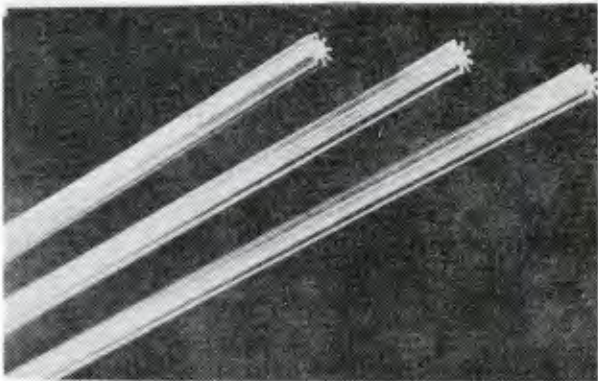


Figure 1 - Type 416 Stainless Steel Pinion Section Produced By Hydrostatic Extrusion

BENEFITS

These projects have demonstrated that hydrostatic extrusion and chemical etching/diffusion bonding are capable of producing acceptable fuze pinions.

IMPLEMENTATION

Implementation will result upon completion of the follow-on FY76 effort.

MORE INFORMATION

More information can be obtained from Mr. Reap, US Army Armament Research and Development Command, ATTN: DRDAR-LCU-M, Dover, NJ, 07801, AV 880-4389 or Commercial (201) 328-3342.

Summary Report was prepared by Gordon Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 6561 titled, "Development of a New Technology for Piercing and Surface Finishing Small Holes in Fuze and Timer Components," was completed by the US Army Armament Research and Development Command in May 1977 at a cost of \$125,000.

BACKGROUND

Mechanical time fuze components must be manufactured very precisely in order to eliminate custom fitting and selective assembly. These components are made of various materials and contain precisely located holes that have close tolerances and fine finishes. Hole diameters are smaller than the thickness of the metal in which they are located. To date, the only known method of producing these fine holes has been to drill and ream them. Conventional piercing methods have not been employed because the practical minimum ratio of hole diameter to metal thickness is one to one. Small diameter holes are difficult to pierce because slender punches are comparatively weak and need to be specially stiffened and guided.

SUMMARY

The objective of this project was to develop a precise method of blanking and piercing that would produce small holes accurately and precisely with regard to diameter, location, and surface finish while at the same time increasing output and reducing equipment and labor costs.

Two concepts were investigated, namely high speed piercing and fine blanking. High speed piercing of small holes requires that the punch be supported over as much of its length as possible. Two commonly used designs for achieving this support are shown in Figure 1. A commercially available variation of one of these punch support systems was tested unsuccessfully. The manufacturer was unwilling to provide a modified version of the supported punch and so this phase of the project was terminated.

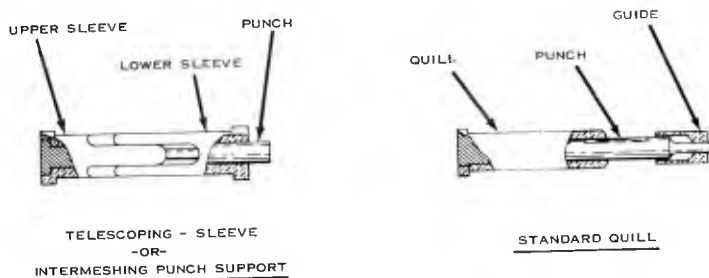


Figure 1 - Two Commonly
Used Types of Quill
Presses

Fine blanking (also known as fine-edge blanking, smooth-edge blanking, or fine-flow blanking) is a process to produce precise blanks and holes in a single operation without the fractured edges normally produced in conventional blanking. In fine blanking, a V-shaped impingement ring is forced into the stock to lock it tightly against the die and to force the work metal to flow toward the punch. In this manner, the part is extruded out of the strip without fracture or die break. Figure 2 illustrates the fine blanking concept.

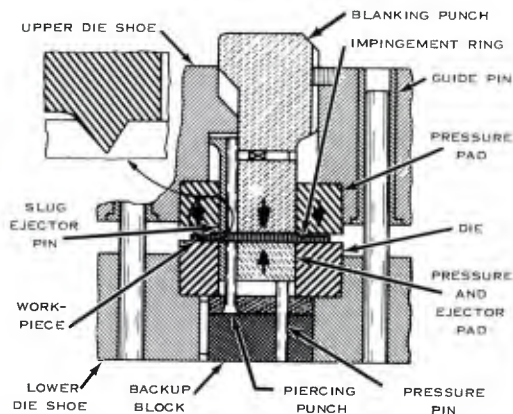


Figure 2 - Typical Tooling For Fine Edge Blanking

Test result indicated that the fine blanking process could yield acceptable parts relative to surface finish and dimensional tolerances. All parts produced had a surface finish of 20 RMS or better and were within $\pm .0005$ inches of design specification.

BENEFITS

This project successfully demonstrated the applicability of the process of fine blanking to US Army fuze production. While an estimate of savings from installed equipment is unavailable because of limited production experience, the quality of parts produced by fine blanking is considered vastly superior to that of parts produced by conventional methods.

IMPLEMENTATION

The results of this project were implemented in MOD Project 577 4847 which purchased five fine blanking presses for use on M577 fuze production at Hamilton Technology, Lancaster, PA, and Bulova Systems and Instruments Corp., Valley Stream, NY.

MORE INFORMATION

Additional information may be obtained from Mr. Tom McKimm, ARRADCOM, AV 880-3265 or Commercial (201) 328-3265.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 678 3901 titled, "Manufacture of Fluidic Amplifiers by Cold Forming," was completed by the US Army Armament Material Readiness Command in July 1980 at a cost of \$290,000.

BACKGROUND

The fluidic amplifier manufacturing processes currently used have not been completely successful in solving the problem of low-cost, large-quantity fluidic amplifier fabrication. The component parts are usually formed by photochemical etching of steel or aluminum laminates. The laminates are then mechanically clamped together to form a modular unit. When the laminate thickness exceeds the capability of the etching process, laminates are stacked to the desired height. This procedure is limited in dimensional accuracy, repeatability, laminate thickness, internal surface quality, and sealing that can be economically achieved.

SUMMARY

The objective of this project was to apply the cold forming process for the less costly, higher quantity production of fluidic amplifiers. The cold forming method would produce fluidic components with better dimensional repeatability and surface finish than what could be produced with the chemical milling and electro-forming processes.

In this project, the techniques of fineblanking and semi-solid-state diffusion bonding (SSDB) were investigated to determine their applicability to the manufacture of fluidic components. Fineblanking, a precision cold forming process, was used to fabricate aluminum alloy (6061) laminates in thicknesses ranging from 0.20 mm to 3.18 mm. Fineblanking differs from conventional stamping in that the edges of parts are sheared cleanly over the thickness of the metal. Conventionally punched parts show "die break," the tearing process that produces rough edges. Figure 1 illustrates, schematically, the difference between the two methods. Fineblanking, however, does have disadvantages, the most significant of which are the presence of die roll and burr on the edges of the punched part. Both die roll and burr interfere with proper sealing between the laminations of an amplifier assembly. These adverse effects can be minimized by secondary operations such as abrasive machining, but this adds to the expense of manufacture.

A representative three-stage fluidic amplifier design was used as a basis for evaluating these processes. The HDL standard laminar proportional amplifier, slightly modified to enhance its compatibility with the fineblanking process, was selected as the critical part to be fabricated. Amplifier and manifold parts were fineblanked, and amplifier modules were bonded by the SSDB process. The complex

contour of the amplifier was reproduced within design tolerances in thicknesses of 0.20 mm and 0.51 mm, but laminates of 1.27 mm thickness displayed excessive die roll. In contrast, manifold plates that contained only slots and circular holes were produced within design tolerances in thicknesses up to 3.18 mm. Overall, with the one exception cited, laminates were produced having good internal shear surface quality and excellent dimensional repeatability.

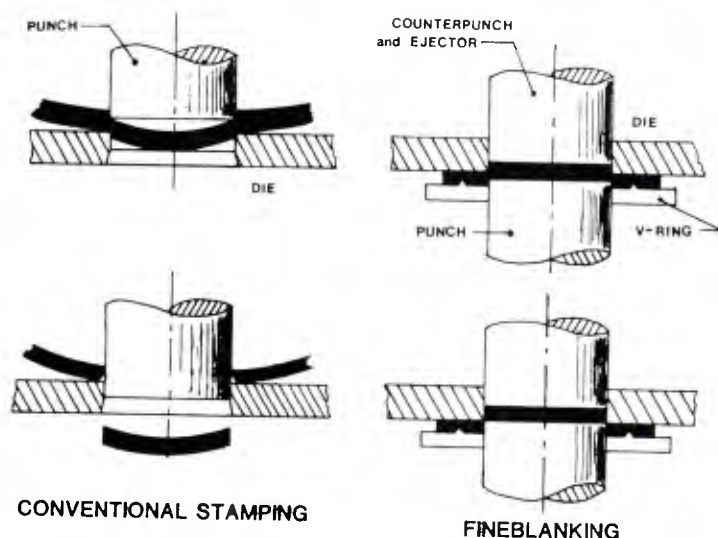


Figure 1 - Comparison of Fineblanking and Conventional Stamping

SSDB is a fluxless brazing process by which aluminum alloy laminates may be sealed together to provide an integral unit. The mating surfaces are clad with a brazing alloy consisting of 90% aluminum and 10% silicon. Bonding is accomplished by raising the temperature to a level just sufficient for the cladding material to diffuse into the laminate surfaces, but not high enough for the cladding material to run into and clog the internal passageways of the unit being bonded. Three modules each of three aspect ratios (0.4, 1.0, and 2.5) were assembled using the SSDB process. Hard tempered laminates were used for the module cover plates and amplifier laminates, but due to the high bonding temperatures, the bonded modules were annealed. This difficulty could be remedied by reheat treatment after bonding.

Pre-bond and post-bond gain tests were conducted on eight of the bonded modules, with all eight showing changes in gain ranging from 8% to 43%. There was no evident pattern in the gain changes. If a bonding-related pattern does exist, a much larger number of samples would be required to define it. After these tests, the bonded amplifier modules were assembled using the fineblanked manifold laminates and were installed on the three-stage amplifier chassis. Gain tests demonstrated satisfactory performance of the whole assembly.

BENEFITS

The results of this project have demonstrated that fineblanking can be successfully used to manufacture high quality laminates. The process can lower the cost of amplifiers in quantity production to about 60% of those fabricated by the etched process when manufactured in quantities of 10,000 parts. The savings would be even greater in larger quantities.

IMPLEMENTATION

It is anticipated that the fineblanking and bonding processes will be utilized in manufacturing sensors for the M-1 Tank stabilization system in the 1983 timeframe. Other applications will follow for sensors for remotely piloted vehicles, missiles, and dual-channel fuel controllers for gas turbine engines. A technical report summarizing the work performed in this project was prepared and distributed.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. J. W. Joyce, HDL, AV 290-3080. A final report titled, "Fineblanking, Diffusion Bonding, and Testing of Fluidic Laminates," dated July 1980, was published by TRITEC, Inc.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 673 7026 and 674 7026 titled, "Effect of Processing Variables on Erosion of Gun Steel," were completed by Watervliet Arsenal in December 1975 and June 1979 at costs of \$75,000 and \$250,000, respectively.

BACKGROUND

The initial project 671 7026 demonstrated that processing variables such as chemistry, melting and forging practices, heat treatment, and mechanical properties influence gun tube erosion on firing. The results of extensive tests, using a special test fixture, concluded that small changes in the steel chemistry lead to large variations in the erosion resistance of steel. The most important property of cannon material noted was the thermal conductivity. This conclusion led to further investigations.

SUMMARY

The purpose of this program was to generate process data on gun tube steel, a variation of SAE 4330, for incorporation into future specifications. The objective was to effect maximum wear life without resorting to coatings. This work was planned as a two-phase effort. The purpose of the first phase was to determine the influence of small chemistry variations of steel on thermal conductivity and, consequently, on erosion rates through sub-scale firing. The purpose of the second phase was to apply the results obtained from sub-scale firing to full-scale firing tests.

The service life of certain gun tubes such as the 105mm, M68 and 8", M201 is determined by the rate at which the bore surface erodes. Erosion is a complex phenomenon involving: chemical reactions of the combustion products with the steel surface; physical interaction of the high-speed stream of combustion products and gases with the bore surface; convective heating of the hot combustion products; and the mechanical action of the moving projectile on the bore surface.

To measure the erodibility of steel, a massive test fixture was designed and built, Figure 1. This fixture incorporates a pressure vessel where a charge of nitrocellulose is ignited; a refractory material nozzle which allows pressure to build up rapidly and consistently, and a replaceable test vent to measure the erosion of various steel chemistries. The hollow cylinder vent is

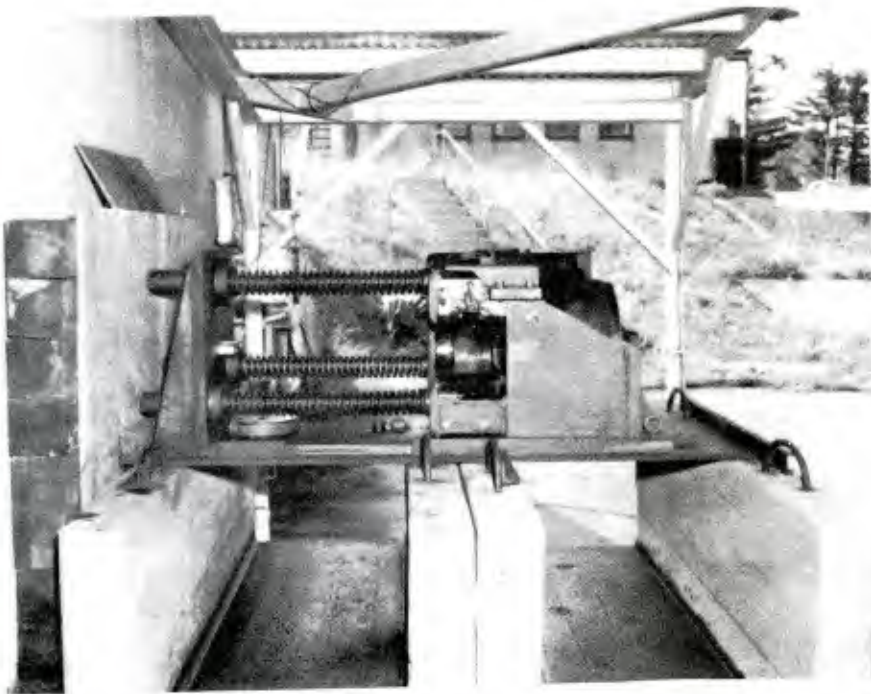


Figure 1 -
Sub-scale Firing
Test Fixture

7-inches long with a 2 3/4-inch OD and 0.735 ID. After several firing impulses, the vents were analyzed for weight loss and changes in the internal diameter. The results of the sub-scale firing showed that a low silicon, high molybdenum composition of SAE 4330 steel decreased the erosion rate. The small elemental variations of alloying components had a large effect on the thermal conductivity of the steel. To substantiate these findings, a full-scale firing test utilizing the 105mm, M68 gun as the test weapon was conducted.

A low silicon, high molybdenum SAE 4335V type steel was rotary forged into a gun tube. Only enough material was available for half a gun tube, so the muzzle half was produced from conventional gun tube steel; and the two were joined to produce one M68 Gun tube. The gun tube was fired at the Wright-Malta Test Station. Erosion rates of the lands and groove diameters were compared to normal gun tubes after 100 rounds. (Figure 2).

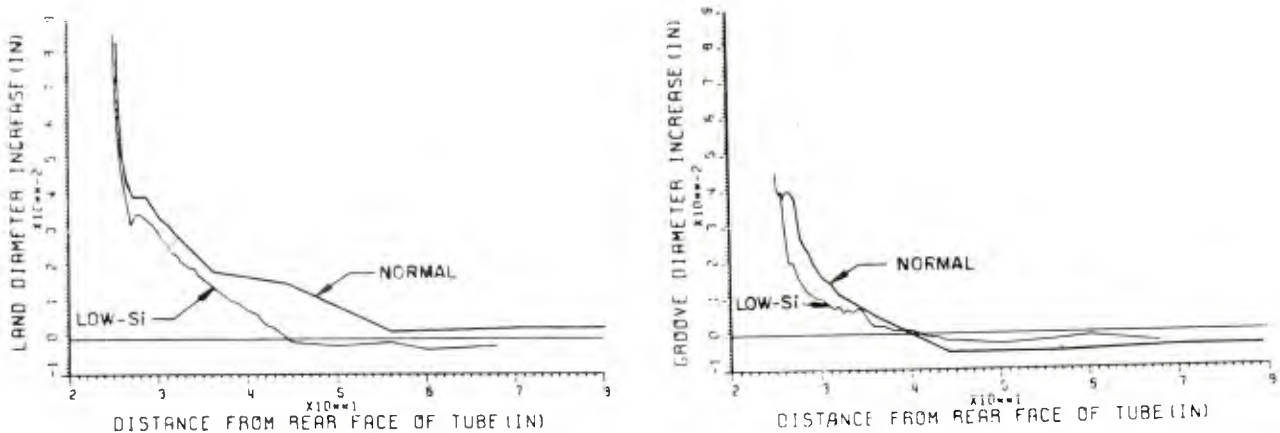


Figure 2 - Erosion Profiles for Normal Gun Steel and Low Silicon-High Molybdenum Gun Steel After 100 Rounds

This project concluded that a reduction in silicon with an associated increase in molybdenum appeared to increase the wear life of gun steel when test fired under sub-scale conditions. However, when the same material was employed in full-scale firing tests, the wear life of the gun tube remained the same, independent of silicon and molybdenum content.

BENEFITS

The low silicon, high molybdenum variation of the steel developed in this program is better able to meet property requirements for modern large caliber gun tubes. However, no cost savings in the manufacture of gun tubes can be documented as a result of this project.

IMPLEMENTATION

Although this program did not conclusively correlate gun tube erosion to the thermal conductivity changed by steel chemistry variations, a spinoff resulted. The specifications for rotary forge preform for gun tubes now incorporates the steel chemistry developed in this effort.

MORE INFORMATION

Additional information may be obtained from Mr. Fran Heiser, Benet Weapons Laboratory, AV 974-4200 or Commercial (518) 266-4200.

Summary Report was prepared by Ron Russell, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 672 7029 titled, "Resolution of Production Problems Associated With Variability in Mechanical Properties," was completed by the US Army Armament Command's Benet Weapons Laboratory in June 1975 at a cost of \$225,000.

BACKGROUND

The variations encountered in mechanical properties of large steel forgings have been a particularly troublesome problem for many years. These aberrations are frequently responsible for high rejection rates and contribute to the failure of structural components throughout a broad spectrum of the steel industry. The mechanical properties of gun tube forgings may vary considerably from point-to-point along their length and even between clock positions within an individual disk. Therefore, the tests conducted on gun tubes are not necessarily representative of the properties of the tube in general. The amount of deformation that a steel forging undergoes at high temperature affects the properties of the metal according to a complex relationship involving the initial stage of the ingot and all subsequent deformations. Earlier work by the Benet Laboratory on low alloy steel cylinders showed that the percent reduction of area (%RA) in forgings of equivalent configuration showed significant variation where the forgings resulted from different ingot positions. Conversely, %RA in similar forgings showed insignificant variation when the forgings came from similar ingot positions. Also observed was significant variation in yield strength and room temperature Charpy impact energy for similar forgings produced from identical size ingots, but different heats of steel. These two conclusions demonstrated the effects of solidification parameters and melting variables upon the mechanical properties in large forgings.

SUMMARY

The objective of this program was to evaluate the effects of forging reduction on the mechanical properties of low alloy, heavy steel forgings. Two identical size ingots were poured from the same heat of vacuum degassed, low alloy steel (modified 4335 with V). The heat (22 tons) was melted in a basic electric arc furnace. The ingots were then forged into stepped-down cylinders. Figure 1 shows the ingots and stepped-forging dimensions. Test specimens were then taken in the transverse orientation, and the mechanical property data were analyzed by the Analysis of Variance Technique (ANOVA) to define variations that might exist. The results of the ANOVA which included 144 tensile, 144 Charpy, and 60 compact tension fracture toughness specimens showed that forging reduction (steps) is responsible for significant variation in all the parameters considered. This analysis concluded that:

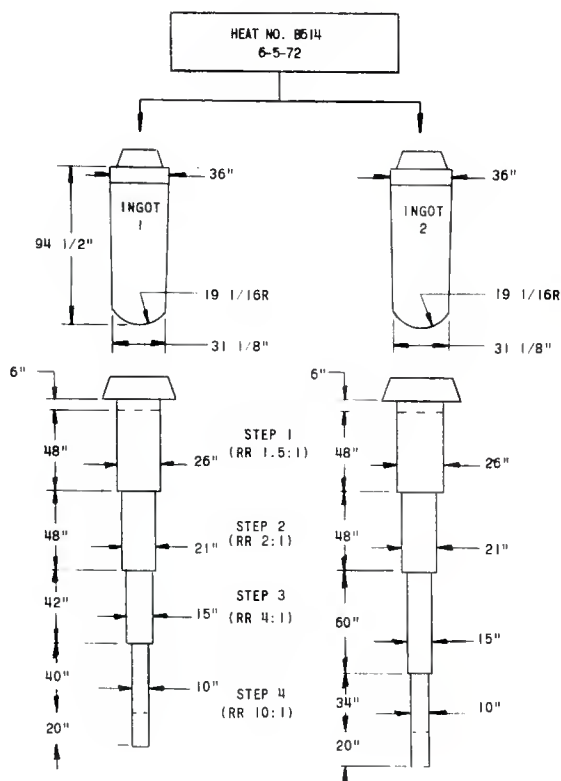


Figure 1 - Schematic of Ingots and Step Forgings

1. An approximate forging reduction ratio of 3:1 produced optimum average values of %RA, Charpy impact, and fracture toughness in this material.

2. Variations in excess of experimental error variance were determined in yield strength, % reduction of area, Charpy impact energy, and plain strain fracture toughness. The variations occurred between different forging reduction of the same ingot in the 1.5:1 to 10:1 range.

3. Significant variation was also measured in Charpy impact energy in separate identical size ingots poured from the same heat.

4. Real variations in carbon concentration were measured in different forging reductions and separate ingots.

The program concluded that chemical inhomogeneity, in particular, carbon segregation on a macroscale, is a major contributor to mechanical property variation in the steel. The mechanical working alters the segregation pattern, but does not eliminate it.

The method of correcting the real problem with large, low alloy steel forgings was identified. The solution is to modify the solidification mechanism, thereby preventing the flow of solute-rich material.

BENEFITS

This project provided the necessary manufacturing technology to upgrade material so that fewer large, low alloy steel forgings fail due to mechanical

property requirements. This has resulted in a reduction in the rejection rate for large caliber gun tube forgings from 13% to 14% with conventional vacuum degassed steel down to less than 2% for electroslog remelting (ESR) forgings.

IMPLEMENTATION

The project results were implemented by gun tube forging suppliers, Cabot Corporation and National Forge. The technology is applicable to the new 120MM gun tube forgings that are being produced by ESR and rotary forging processes.

MORE INFORMATION

Additional information may be obtained from Mr. Vito Colangelo, Benet Weapons Laboratory, Watervliet, NY, AV 974-5517 or Commercial (518) 266-5517.

Summary Report was prepared by Ron Russell, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7087 titled, "Application of High Frequency Induction Heating Method for Hot Coiling of Springs," was completed by the US Army Armament Material Readiness Command in December 1980 at a cost of \$532,000.

BACKGROUND

Presently, the heat source commonly used for hot winding springs is a gas-fired furnace. The induction coil method of heating the springs was developed and found to be feasible under MMT Project 670 7087. It was found that the induction method of heating was superior to gas for the control of surface finish, dimensional stability, hardness, grain size and microstructure. It was also determined that this technology was feasible for a variety of spring sizes.

SUMMARY

The objective of this project was to design and fabricate hot spring winding equipment and to implement the process if successful. Alternative designs were evaluated and one design was selected. The hot spring winding equipment, based on the selected design, was purchased from a contractor. Figure 1 is a photograph of the equipment in operation.

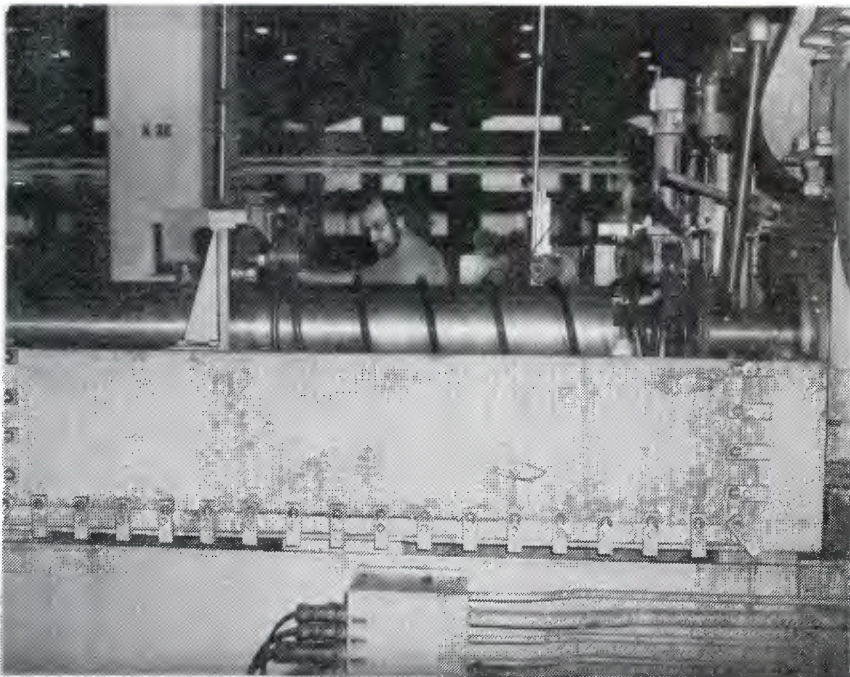


Figure 1 -
Hot Spring Winding
Machine

Initial spring forming work was directed to the production of the M140 tank gun recoil spring. A series of springs were wound from 6150 steel to establish machine set-up parameters. Considerable difficulty was encountered in adjusting the machine to properly form the first and last wrap of the spring. A 250 maraging steel spring was wound, heat treated, weighed, and measured. Based on these measurements, the mandrel was turned down and additional machine adjustments made. Additional springs were formed using both carbon steel and maraging steel. The carbon steel springs were formed to the proper physical configuration while the maraging steel springs exhibited improperly formed end wraps.

The quench system on the equipment was modified to provide a one and one-half inch discharge line and an air agitation device. The induction heating system was adjusted and the vane switch control system was modified to provide the capability to form variable fractional turn wraps on the springs.

New mandrels to form the above springs were manufactured while the spring material was centerless ground and end tapered.

Through a series of trials and adjustments, the machine was set up to form the recoil spring for the M-1 Tank. The formed springs were heat treated, weighed, and measured. Because there was no fixturing available, the end coils of these springs were not ground as required. However with this exception, the springs conformed to drawing requirements. The machine was then set up for production of the M101-A1 equilibrator spring. A series of springs were formed, heat treated, weighed, measured, and end ground on open set up. These springs also met drawing requirements.

The M101-A1 spring has a wire diameter of 0.687 inches, a mean diameter of 4.94 inches, and a free height of approximately 26.12 inches. The recoil spring for the M-1 Tank has a wire diameter of 1.188 inches, a mean diameter of 11.80 inches, and a free height of 35.20 inches. The two springs illustrate the wide range of spring sizes the equipment is capable of forming.

Some difficulty with the quench system portion of this project is still evident. During metallographic evaluation of the test springs, one spring exhibited a small crack which was attributed to the severity of the synthetic quenchant used. Other springs were checked for cracking by the use of a magnetic particle test and no other cracks were found. A change in quenchant or an increase in quenchant temperature is expected to further reduce the possibility of quench crack formation.

BENEFITS

Benefits to the Army include the development of an improved spring manufacturing technique which provides accurate, repeatable spring winding while reducing heat time and material decarburization. The development of this equipment provides an alternative source of large spring manufacture which will aid in reducing procurement problems and delays. This equipment will also be beneficial in the development of new large springs and other short run work.

During the development of this process, other developments in furnace heating has greatly reduced the heating time in conventional spring making. Current comparison indicates that conventional techniques can form a large spring in 18 man-minutes while with the new induction system, a large spring may be formed in 16 man-minutes. This represents an 11% reduction in labor.

IMPLEMENTATION

The result of this project is self-implementing and will be used when Rock Island Arsenal begins production of the recoil mechanism spring for the M-1 Tank. During the course of this project, a production spring maker was trained in the setup and operation of this equipment.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. John Jugenheimer, Rock Island Arsenal, AV 793-4135 or Commercial (309) 794-4135.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 676 7203 titled, "Application of Least Cost Tolerances and Finishes Related to the Production of Gun Components," was completed by the US Army Armament Materiel Readiness Command (Watervliet Arsenal) in November 1977 at a cost of \$52,000.

BACKGROUND

The products manufactured by Watervliet Arsenal range from massive major cannon tubes weighing in excess of 12,000 pounds to minor items weighing less than one pound. Some of the items, although considered to be minor components, are extremely complex and therefore difficult to produce. This situation is further complicated by dimensional tolerance and surface finish requirements. Tolerance and surface finish specifications for major components can also be difficult to obtain and therefore are a source of manufacturing difficulty.

The source of the manufacturing difficulties noted above is the original product design. Many designers are not familiar with general overall machining cost factors and do not know, for example, that specifying a 16 RMS finish in lieu of a 63 RMS finish increases the component finishing cost by as much as 300%.

Final product tolerances of ± 0.002 will cause dimensions to be controlled much more closely than ± 0.002 during the manufacturing cycle in order to insure that the final requirements are met. Locating or holding fixtures, tooling, gages and the general step-by-step manufacturing process must be controlled and continuously monitored in order to satisfy end item tolerance and surface finish requirements. It is not difficult to specify or establish any particular tolerance or surface finish; it may be extremely difficult and costly to produce them.

SUMMARY

The objective of this project was to locate areas of potential cost reduction through tolerance and/or surface finish changes and to develop ready references showing a variety of engineering data relative to machining costs and tolerance/surface finish specifications. A product survey was conducted to determine the areas of greatest potential savings. Tests to establish various technical parameters relative to surface finish and part specifications were completed. Data generated from test results were forwarded to a private company for development of a slide chart showing machining limitations and tolerancing stack up. After considerable time and effort had been expended, it was determined that such a slide chart was impractical due to the many complex and changing machining situations. It was possible, however, to develop two charts containing information relative to surface finish and these are shown in Figures 1 and 2.

TECHNIQUE	MICROINCHES												
	2000	1000	500	250	125	63	32	16	8	4	2	1	0.5
FLAME CUT													
SAWING													
PLANING, SHAPING													
DRILLING													
CHEMICAL MILLING													
DISCHARGE MACH.													
MILLING													
BROACHING													
BORING													
TURNING													
ELECTROLYTIC GRINDING													
BURNISHING													
GRINDING													
HONING													
POLISHING													
LAPPING													
SUPERFINISHING													

 = AVERAGE INDUSTRIAL APPLICATION.
 VALUES MAY VARY UNDER SPECIAL CONDITIONS.

Figure 1 - Finishes Produced by Various Techniques

The 105mm, M68 Breechblock, the 105mm M68 Gun Tube, and the 105mm M68 Breech Ring were surveyed for potential cost reduction through tolerance surface finish change. It was determined that in all cases the component tolerances and surface finishes specified are fully justified.

BENEFITS

The charts shown in Figure 1 and 2 have been made available as a reference guide for engineers and designers.

IMPLEMENTATION

The results of this project have been distributed within Watervliet Arsenal.

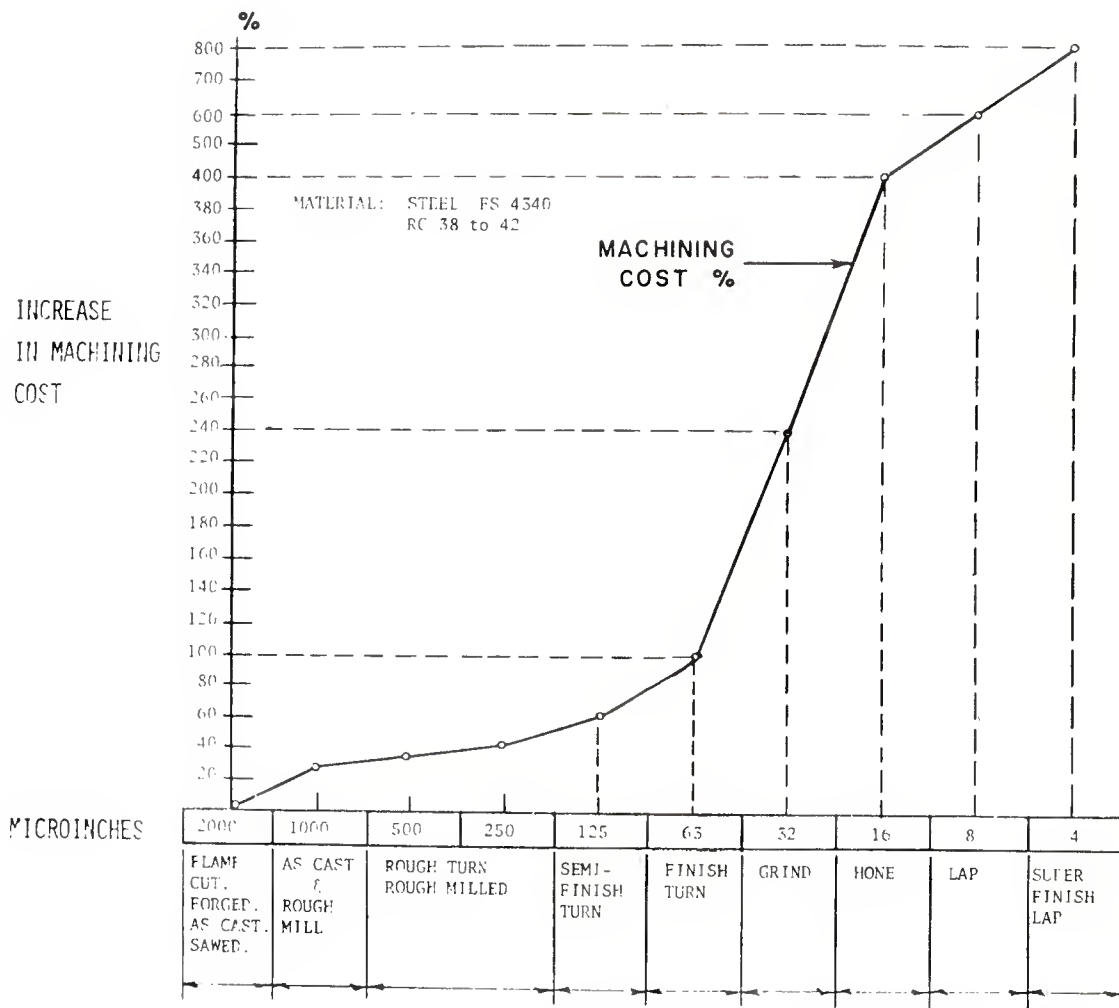


Figure 2 - Machining Costs Versus Surface Finish Specified

MORE INFORMATION

Additional information may be obtained from Mr. John Rodd, Watervliet Arsenal, AV 974-5611 or Commercial (518) 266-5611.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 677 7213 and 679 7213 titled, "High Speed Chromium Plating Technique," were completed by the US Army Armament Materiel Readiness Command in September 1979 and December 1980, respectively, at a total cost of \$465,000.

BACKGROUND

The present process of plating gun tubes requires considerable time and space. Many gun tubes are now plated with hard chromium to thicknesses of at least 5 mils. A thickness of 10 mils is projected for future requirements. Deposition of 5 mils of chromium from a catalyzed chromic acid bath by conventional methods requires 5 to 6 hours at a current density of 0.31 amp/sq cm. Deposition of 10 mils will require 10 to 12 hours.

Gun tubes are normally positioned vertically for plating which requires a vertical space over twice the length of the gun tube. Fast-rate electrodeposition (FRED) of chromium uses considerably higher current densities (5 to 20 times) than conventional gun tube plating. Use of a full length anode for FRED of chromium is not feasible because the required current might be 40,000 to 50,000 amperes. In gun tube plating, one of the practical limits is the amount of current which can be introduced into the anode and the gun tube. A short moving anode system with the gun tube in a horizontal position is practical with FRED of chromium.

With a practical limit to the amount of current which can be introduced to the gun tube-anode system, FRED of chromium can increase the productivity of a plating unit about three times because the FRED operates with an electrochemical efficiency of about 40 to 50 percent. By comparison, conventional tank plating is at 12 to 15 percent efficiency.

SUMMARY

The objective of this project was to develop a new high-speed chromium plating process for gun tubes. Equipment and procedures were developed during this project for plating chromium inside 1.2m long sections of rifled and smooth bore gun tubes using a moving anode, high-current density and high-velocity solution flow.

For the rifled tube, the minimum target deposition rate of 10 m/min on the center of the lands was achieved at a current density of 2.4 amps/sq. cm. Faster plating rates were possible at high current densities, but the 2.4 amps/sq. cm. appeared to be near optimum for obtaining the most uniform deposit on the lands and grooves.

Both conforming anodes (which revolved while traveling through the tube to match the rifling) and smooth anodes (which did not rotate while traveling through the

tube) were evaluated for plating the 1.2m lengths. The conforming anode deposited metal with a ratio of about 1.2/1 for the land/groove center line thicknesses. Chromium thickness on the edges of the lands was typically about twice that of the center of the land. Chromium thickness at the base of the land was typically about 15 and 30 percent of the thickness at the center of the land for the round and conforming anodes, respectively.

Adherence of the chromium to the gun steel was excellent when a reverse current treatment was used. The moving anode provides an activation to the steel because the current density gradually increases as the anode approaches each spot. Physical properties of the FRED chromium electroplate, including both as-plated hardness and hot hardness, were within the common limits for conventionally plated hard chromium.

Alternative bath compositions, including more concentrated baths, lower chromic acid-catalyst ratios and a mixed catalyst bath, did not improve the throwing power of the chromium plating process significantly. Adding fluosilicic acid as a replacement for part of the sulfuric acid made a small improvement in throwing power but the change was not considered significant.

An extension of the project was authorized to investigate the rapid chromium plating of the smooth bores of gun tubes. This task required the removal of the rifling from the 1.2m long tubes and plating chromium at higher current densities and rates than were used with the rifled tubes. Relatively low current densities such as 2.4 amp/sq. cm. were used with the rifled tubes to prevent excessive build-up of chromium on the corners of the lands.

Although it was necessary to use lower currents and shorter anodes than were planned, because of equipment limitations, full length sections (1.2m long) of smooth bore tubes were chromium plated with the moving anode system. Plating rates of 12 and 20 m/min were achieved at 3.9 and 6.2 amp/sq. cm., respectively, Table 1. These plating rates are about 25 times as fast as conventional plating. With a closer and more uniform spacing between the anode and the tube, and with more cooling capacity, smooth-bore tubes can be plated using the moving anode and rapid solution flow process.

Table 1 - Calculated Plating Rates as a Function of Current Density

Current Density		Plating Rate	
$\frac{\text{amp}}{\text{cm}^2}$	$\frac{\text{amp}}{\text{in}^2}$	$\frac{\text{m}}{\text{min}}$	$\frac{\text{mil}}{\text{min}}$
2.4	15	6.4	0.25
3.1	20	7.6	0.30
3.9	25	12.0	0.47
6.2	40	20.0	0.80

An "Automated Pump Through Flow System" was installed and successfully tested. The system consists of anode and cathode fixtures, tanks, pumps, valves, piping, and apparatus and control instruments for heating, cooling, and flow of the required chemical solutions. The technical data package now contains the most feasible approach for high speed plating. It contains the specification requirements for the "Solution Flow System" and the specifications for procurement. Detailed steps of the process for plating cylinder bores is included for controlling and maintaining the chemical solutions.

BENEFITS

The process time for this new process for application to the 155mm M185 cannon tube is estimated to be 3.3 hours as compared to the current production process time of 9.5 hours. With a more accurate process control, it is estimated that this technique would significantly reduce or eliminate the need to grind the powder chamber to size after chrome plating. The process results in less air and water contaminants compared to the conventional process which will ease the problems and costs in environmental controls. The new facility design eliminates the need for deep, large tanks, deep pits and high overhead cranes.

IMPLEMENTATION

A copy of the Technical Data Package, which includes the plating procedure, illustrations of the facility equipment and specifications drawings, has been sent to the Chief of Mfg. Engineering Operations at Watervliet Arsenal for review on the establishment of a facility for production plating of 120mm gun tubes. The data and operating parameters generated during this project and during the prototype development will be further utilized to include a production facility with a capability for plating any portion of the bore of any specified caliber weapon.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. V. Greco, ARRCOM, AV 974-5717 or Commercial (518) 266-5717. Final reports titled "Development of a Method for Rapid Chromium Plating of Gun Tubes," and "Rapid Chromium Plating of Gun Tubes," were published by Battelle Columbus Laboratories on July 31, 1978, and June 29, 1979, respectively.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 673 7240 titled, "Application of New Processes for the Rapid Boring of Gun Tubes," was completed by the US Army Armament Materiel Readiness Command in November 1978 at a cost of \$50,000.

BACKGROUND

The Boring Trepanning Association's rapid boring system for gun tubes has been applied at Watervliet Arsenal and has reduced actual boring time by 65 percent and attendant tool maintenance cost by 80 percent. In this system a pack reamer is replaced by a trepanning type tool utilizing high velocity coolant to flush chips through the interior of the boring bar, thereby allowing higher feeds and speeds and improving the accuracy normally obtained with pack reaming.

Boring operation costs could be further reduced if a method for centering the gun tube was developed that did not require the indicating of the gun tube in the boring lathe. In addition, faster cutting rates could be obtained with a more efficient coolant.

SUMMARY

The objectives of this project were to develop an automatic set-up fixture and evaluate the use of water soluble coolants. Limited testing on a modified LeBlond gun boring lathe indicated the coolant inductor could be modified to accommodate an internal centering mechanism. Additional coolant system modifications required for the water emulsion type coolant were considered to be minor and straightforward.

To test the principle of locating the end of the tube in a steady rest using a center located in the coolant inductor (Figure 1), a live center adaptor (Item 1) was manufactured to fit in the bore of the coolant inductor (Item 2). A gun tube was then indicated at the breech end to locate it in the center of the four jaw chuck. The muzzle end was located on the live center and the steady rest rolls were adjusted into place. During this test, it was observed that the tube was located satisfactorily and the time was reduced, even though additional time was required to advance the coolant inductor and insert and remove the center.

As a result of the success of these tests, a new coolant inductor was designed and manufactured. The new inductor (Figure 2) does not appear too different from the original inductor except that instead of a handle on top to advance the inductor and maintain pressure between the inductor and gun tube, the new inductor has two feed wheels (Items 1 and 3). The upper feed wheel (Item 1) controls the application of sealing pressure between the face of the gun tube and the rotating

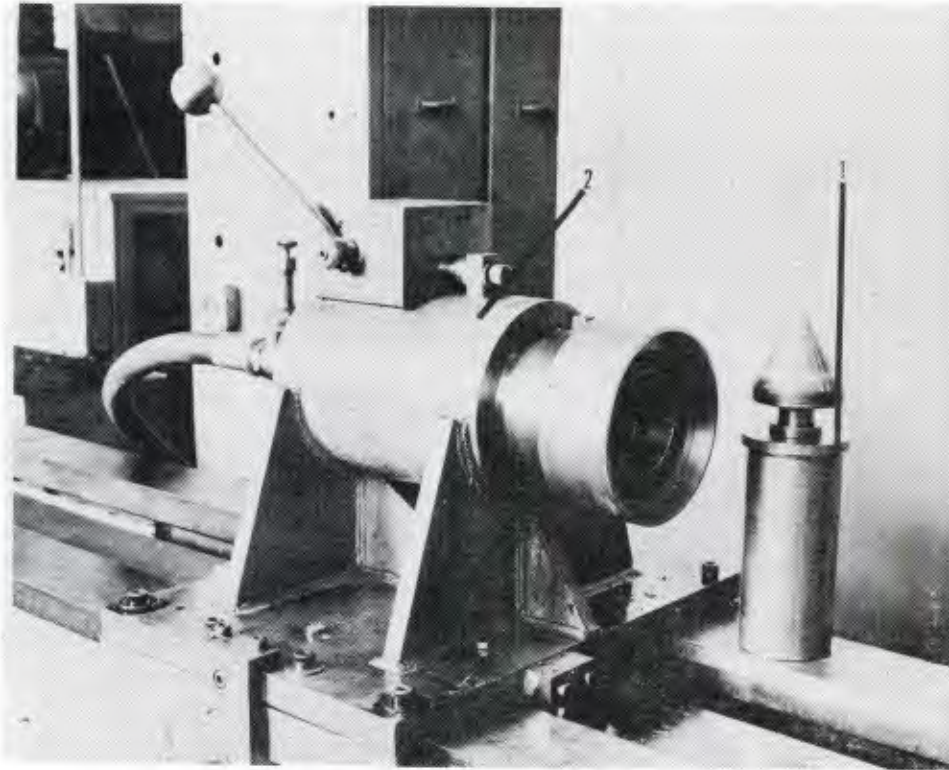


Figure 1 -

Coolant Inductor

1. Live Center Adaptor
2. Coolant Inductor Bore

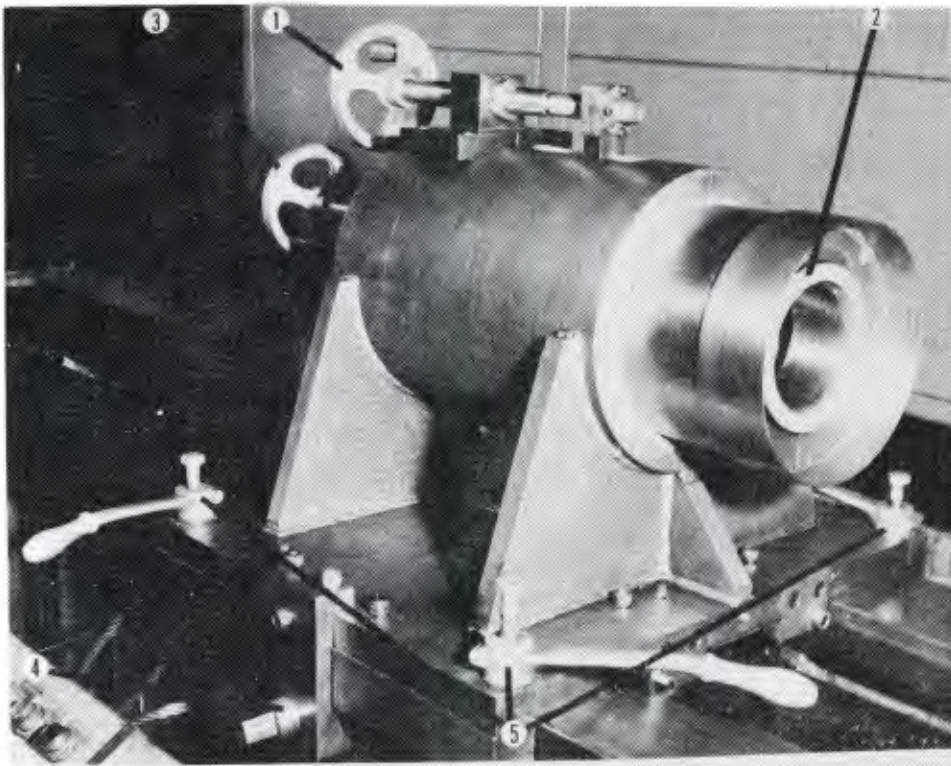


Figure 2 -

New Coolant Inductor

1. Feed Wheel
2. Rotating Seal
3. Feed Wheel
4. Gear Rack
5. Clamps

seal (Item 2). The lower feed wheel (Item 3) advances and retracts the live center within the coolant inductor. The coolant inductor is advanced to the proper position on the gun tube along the machine by a gear located on a gear rack (Item 4). The total unit is clamped in place using four clamps (Item 5). Testing of the coolant inductor which incorporates the internal centering unit has shown that setup time was reduced by 25 percent.

The remainder of this project consisted of modifying the boring lathe so that a water emulsion coolant could be used. A gear pump was replaced with a centrifugal type pump and was equipped with a special intake to protect the pump from small chips and heat treat scale carried into the system from the gun tube bore. In addition, the complete unit was repiped to provide for pump lubrication and to provide the required coolant to the inductor. The existing refrigeration unit proved to be inadequate and was replaced with an evaporation condenser.

Cutting tests demonstrated that cutting speed could be increased from 96 RPM to 160 RPM and that feed rates could be increased from .025 inches to .030 inches. As a result, cutting time was reduced by approximately 50 percent.

BENEFITS

Boring time for the 105mm M68 gun tube was reduced by four hours per gun tube with the use of boring equipment modified to the specifications developed by this project.

IMPLEMENTATION

The results of this project were implemented at Watervliet Arsenal from 1976 through mid 1977. In 1977, the results of another MMT project on the application of bore guidance to mid-caliber gun tubes was implemented, eliminating any further benefit from the application of MMT project 673 7240.

MORE INFORMATION

Additional information may be obtained from Mr. Tom Wright, Watervliet Arsenal, AV 974-5319 or Commercial (518) 266-5319.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 677 7726 and 678 7726 titled, "Application of Cold and Warm Forging," were completed by Watervliet Arsenal in July 1980 and April 1981 at costs of \$592,000 and \$110,000, respectively.

BACKGROUND

At the inception of this three-year effort, the capability for hot forging cannon tubes on the Watervliet integrated rotary forge line was well established. However, the machine capabilities for warm or cold forging were not known. It was believed that a potential for precision forging tubes at lower cost existed if the process parameters could be better defined and understood. The objective of this effort was to extend the capabilities of the rotary forge system by developing procedures for cold and warm forging and the use of non-standard preforms. It was planned that a 105mm M68 Gun Tube boring operation and a finish honing operation would be replaced by a rough honing operation only, as a result of the warm forging process.

SUMMARY

Preforms were purchased and forged into the blanks to be used for cold forging of the 105mm M68. Instrumentation of the forge machine was also completed. This included a series of transducers placed at key points to measure the loads/forces under the hammers and also measure the longitudinal forces generated by the movement of the chuckheads. In addition, encoders were placed on both chuckheads to measure velocities during forging. Trial data on their functionability was obtained during hot forging production runs. The optimization program for the warm radial forging showed the following:

1. It is possible to warm radial forge the 105mm M68 Gun Tube. However, care should be taken not to forge the material in the embrittlement range of 427C to 538C. (800F-1000F)

2. The geometry of the tool has to be designed in such a way as to not exceed the capacity of the machine. This means that both the entry angles and contact angle of the tool with the workpiece have to be designed to limit the load requirements within the capacity of the machine.

Based on an analysis of different tool geometries, preform dimensions, and preconditions (lubricated or non-lubricated), the following is recommended:

1. Warm radial forging of the muzzle end should be done under the following conditions:

- a. A forging temperature of 400C - 424C (750F - 800F).
- b. A reduction in the non-lubricated condition of 15 percent maximum.
A reduction in the lubricated conditions of 20 percent maximum.
- c. A hammer contact angle of less than 60 degrees using the non-lubricated preform.

A hammer contact angle of less than 75 degrees using the lubricated preform.
- d. A compound entry angle of 5 degrees and 2 degrees on the cold forming tools. Tool relief angles which exceed the contact angle.

2. Warm radial forging of the breech end should be done under the following conditions:

- a. A forging temperature of 400C - 425C (750F - 800F).
- b. A reduction in the non-lubricated conditions of 10 percent maximum.
A reduction in the lubricated conditions of 10 percent maximum.
- c. A hammer contact angle not to exceed 75 degrees for the non-lubricated preform.

A hammer contact angle not to exceed 75 degrees for the lubricated preform.
- d. A compound entry angle of 5 degrees and 2 degrees on the cold forging tools. Tool relief angles which exceed the contact angle.

3. Care must be taken to maintain the temperature in the specified range. Higher temperatures will result in the working of the component in the temper-embrittlement range.

4. Potential problems were identified as:

- a. The maintenance of billet temperature and mode of heating of the billet.
- b. Lubricant application.
- c. Secondary handling of the billet for the final operation.
- d. Selection of tool material.

BENEFITS

1. Quantifiable - Direct production of forging preforms from primary metal producer's products, and the warm/cold forging processes are expected to result in

cost savings due to a reduction in the number of machining operations required. The economic analysis of this project indicates peacetime production savings of \$5.9 million and mobilization savings of \$17.3 million during project life.

2. Non-Quantifiable - These benefits include an increase in the process capability to forge products not being considered due to unknown machine limits, an improvement in response time for unexpected requirements, and a broadened procurement base for preforms.

IMPLEMENTATION

These projects represent the first and second years of a three-year inter-related effort. Implementation of the results will not occur until completion of the total program.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Leonard Liuzzi at Watervliet Arsenal, AV 974-5827 or Commercial (518) 266-5827.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 678 8045 titled, "Improved Tube Straightening," was completed by the US Army Armament Material Readiness Command in June 1980 at a cost of \$65,000.

BACKGROUND

Previous manufacturing methods and technology programs have made it possible to reduce the size of the forgings used in manufacturing gun tubes. By reducing steel purchases and inherent metal removal operations, stock distribution has become a more critical operation. Closer tolerances must be held on the forging straightness. Stock distribution is accomplished by bending the forging to a straight condition that will provide material for machining both the bore and the outside diameter of the tube. The pressure previously considered acceptably accurate must be updated to provide the operator with the capability of monitoring and controlling the press operation to these more precise requirements.

SUMMARY

The purpose of this project was to develop a sensing and control system that would electronically measure and monitor gun tube deflection in pressing operations. The system would provide accurate indications of gun tube deflection. After checking dimensionally permanent deformation obtained during the bend, an accurate return would be made possible by the servo system so that additional corrections can be made to the tube straightness. The addition of a sensing and control system would minimize the error in reading tube deflection. The digital reading, a well defined figure, would improve the operator's efficiency, would minimize the training required to use the equipment, and would decrease the experience required to become proficient.

An existing hydraulic press was retrofitted with position sensing and ram force indicators. A method was designed to mechanically attach the digital system unit, a Pathfinder 5 Model 8780, to the press. Fifty-three gun tubes were passed for the purpose of evaluating the system. With the digital readout monitoring the ram position, the operator could control the bend within .010 to .015 inch and practically eliminate the possibility of "going through" the bend. The operator had complete control within that range. The digital readout system removes all guessing or estimating from the pressing operation and replaces it with an accurate, proven and easily read digital display which anyone can read and record with a minimum of instruction. Training an operator to this system of gun tube pressing is a simple matter of teaching him how to read a digital display.

BENEFITS

There are several benefits realized from this project. The time required to press a gun tube within acceptable dimensional tolerances was reduced by a minimum of 50 minutes per gun tube. Pressing costs are reduced 12% or \$13.56 per tube. Within a 12-month period (Mar '80 - Feb '81) approximately 625 tubes were pressed using this system. This represents a savings of \$8,475.00. The accuracy of the system makes it possible to work within a selected bend or press tolerance of .010 to .015 inch. This compares very favorably with the former method of using a scale, pointer and chalk. The simplicity of the digital readout system makes training a simple matter and thus reduces training or break-in time and also requires minimum skill for operating. Savings can also be realized by pressing tubes that otherwise would be rejected due to poor stock distribution.

IMPLEMENTATION

The digital readout system is being utilized in the tube straightening operation. The digital readout system was physically attached to a hydraulic press during February 1980. The readout system is readily adaptable to all hydraulic presses currently in use at Watervliet Arsenal. Plans are to obtain additional readout systems that will be applied to these presses.

MORE INFORMATION

Additional information may be obtained by contacting the project officer, Mr. C. LaRoss, Watervliet Arsenal, AV 974-5611 or Commercial (518) 266-5611.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project M76 6382 titled, "Health/Safety Processing Procedures for Manufacture of Depleted Uranium Components," was completed by the US Army Materials and Mechanics Research Center in August 1977 at a cost of \$60,000.

BACKGROUND

There were no procedures covering industrial manufacturing and fabricating standards for depleted uranium (DU) processing. Such standards were needed to resolve production problems involving risk of fire, heavy metal poisoning, radiation hazard, and hot metal industrial accidents. Although health and safety precautions had been exercised in the processing of depleted uranium at various installations, official Army procedures had not yet been documented.

SUMMARY

The objective of this project was to compile and publish radiation and industrial safety procedures for the processing of depleted uranium into munitions. A literature search was conducted and appropriate manufacturing locations were visited. A draft report was prepared and distributed to 55 Government agencies for review and comment. As a result of the comments received, an additional section on stress corrosion was added to the report. The report was finalized and published as DARCOM Handbook 385-1.1-78, Safety Procedures for Processing Depleted Uranium.

BENEFITS

Safety procedures necessary for the manufacture of depleted uranium penetrators are now standardized and available to Army personnel.

IMPLEMENTATION

DARCOM Handbook 385-1.1-78 has been printed by Letterkenny Army Depot and issued as part of the DARCOM Handbook Series.

MORE INFORMATION

Additional information may be obtained from Mr. Sid Levin, US Army Materials and Mechanics Research Center, AUTOVON 955-3605 or Commercial (617) 923-3605.

Summary Report was prepared by Alan L. Peltz, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology project R77 3121 titled, "Application and NDT of Line Pipe for Motor Components," was completed by the US Army Missile R&D Command in March 1979 at a cost of \$325,000.

BACKGROUND

Considerable efforts have been made to reduce rocket motor component costs. These efforts are primarily in the manufacturing methodology area with the motor design and material specifications regarded as fixed. While this work has reduced rocket motor costs, rockets are still not cost-competitive with tube artillery in the area of fire saturation mission. Production costs are also critical to a high volume and performance system such as the VIPER or MLRS.

A promising method for fabricating low-cost metallic rocket-motor cases exists in using a pipe or tube mill product of appropriate size and of sufficiently high yield strength to be effective. To achieve the high yield strength from a low-alloy, low-cost steel, the steel must be quenched and tempered. A previous R&D program demonstrated that commercial gas or oil transmission pipe could be quenched and tempered to the desired yield strength. Because of this relatively new use of line pipe for rocket motor cases, the manufacturing methods and technology is not available for production capability.

SUMMARY

The objective of the program was to investigate the use of commercial pipe or tube mill products for low-cost rocket motor cases. The work for this program was contracted to Battelle, Columbus Laboratories. All material processing in this program utilized commercial practices so that the manufacturing technology would be readily available to the production of motor cases.

This program is being conducted in two phases. The first phase involves the study of concepts for using pipe mill products and the selection of the most promising concept.

The design of the motor case considered is shown in Figure 1. Initially, attempts were made to obtain off-the-shelf or warehoused tubes. When this was unsuccessful, tubes were made to order by two tube manufacturing companies. Quantities of AISI 1026 spiral-welded and AISI 1035 electric resistance-welded (ERW) pipe were purchased for heat treatment. In the course of the experimental heat treating of the ERW pipe, overwelding of the ERW joint was necessary to obtain satisfactory joint properties. Two methods of heat treatment were investigated. These were furnace and induction heat treating. The heat treatment developed consisted of induction hardening (austenitizing and quenching) the pipe in the horizontal position, followed by batch furnace tempering.

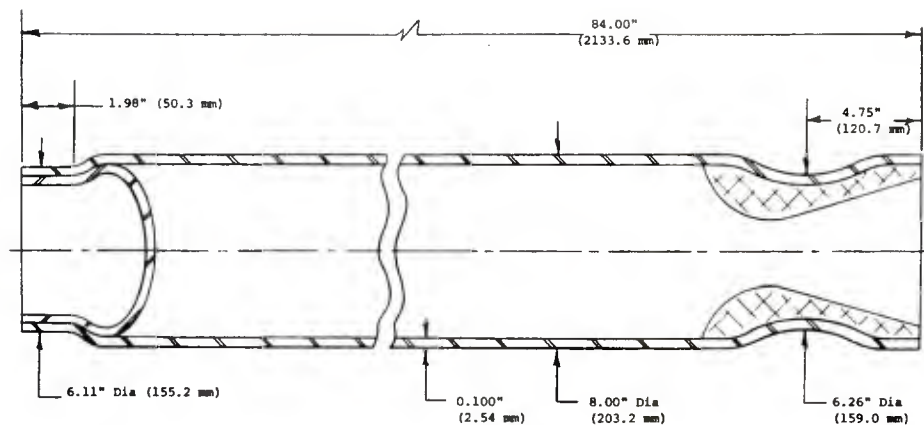


Figure 1 -

Experimental Rocket
Motor Case

None of the tube or pipe that was found feasible for this program is produced to size tolerances that are within the relaxed motor case tolerances. Even if the tube or pipe were within these tolerances, the heat treatment operation could introduce distortion that could be beyond the relaxed size tolerances. Thus, various types of sizing operations were identified. These sizing operations included shear forming, drawing over a mandrel, sink drawing, plug drawing, radial forging, and explosive sizing. Radial forging and explosive sizing were chosen for further investigation.

For the purpose of estimating the cost of a completed rocket motor case, several fabrication sequences were generated by combining the various process options that were being evaluated. The process options were evaluated both technically and economically. If any process option was determined to be unsatisfactory, either technically or economically, the fabrication sequences incorporating that particular process option was abandoned. The process options that were evaluated in this program are listed in Table 1 along with notations regarding technical and economic feasibility.

Operation	Feasible Technically	Feasible Economically
Tube fabrication		
(1) ERW with overweld	Yes	Yes
(2) ERW without overweld	No, low ductility	Yes
(3) Spiral weld by submerged-arc welding	No, excessive weld reinforcement, major dimensional deviations at weld joint	Yes
(4) Spiral weld by GTA	Probably, not evaluated	No
Inspection		
(1) Visual	Yes	Yes
(2) Eddy current of ERW joint by fabricator	Probably, not evaluated	Yes
(3) Ultrasonic	No, pipe wall too thin	Yes
(4) Radiographic	No	Probably not
Heat treatment		
(1) Induction harden	Yes	Yes
(2) Induction temper	No, not controllable at tempering temperature	Yes
(3) Furnace harden	No, erratic quenching response	Yes
(4) Furnace temper	Yes	Yes
Straighten and size		
(1) Explosive	Yes	Yes
(2) Radial forming	Yes	Yes
(3) Tube spinning	Probably, not evaluated	Yes
(4) Sink drawing	Possibly, not evaluated	Yes
(5) Mandrel drawing	Possibly, not evaluated	Yes
(6) Fixed-plug drawing	Possibly, not evaluated	Yes
Form nozzle and front-end closure		
(1) Explosive	No	Probably not
(2) Radial forging	Yes	Yes

Table 1 - Process Options
For Fabricating Motor Cases

The final fabrication sequences were made up of process options that were both technically and economically feasible and are shown in Figure 2. These sequences also include various auxiliary operations that are essential to complete the fabrication of the rocket motor case. The cost of each of the fabrication operations was calculated based on a combination of quoted costs and Battelle experience.

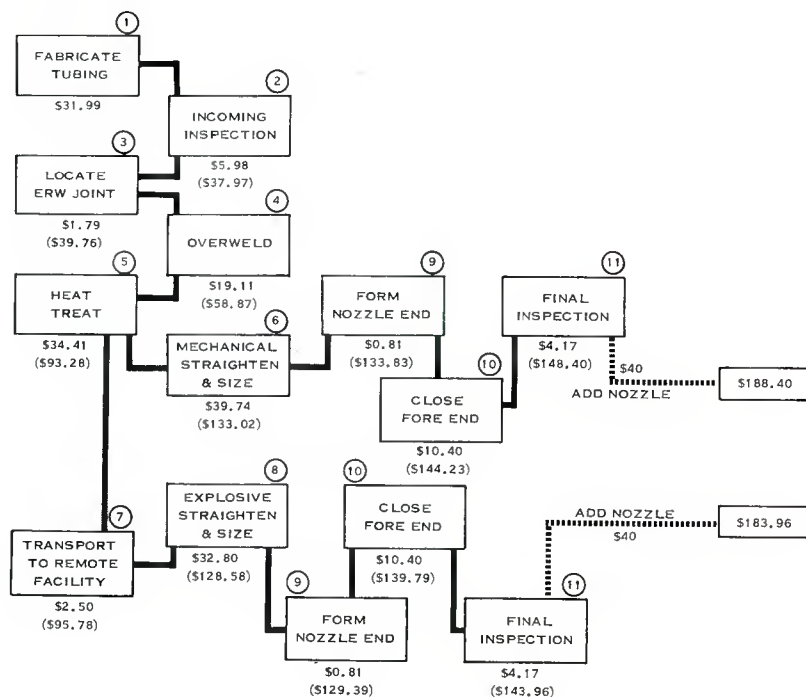


Figure 2 - Operations and Costs For Fabricating Motor Cases

BENEFITS

When the program began, motor cases for free flight rockets cost \$162 each. With MMT, it was estimated that the costs could be reduced to \$49 each. By the end of Phase I, the projected missile case cost using the MMT results had escalated to approximately \$190. Currently, estimated costs without using the MMT results are slightly over \$300 per case for the new MLRS. With the proposed MMT, it is estimated that the costs can be reduced to \$224 per case.

IMPLEMENTATION

A technical report, T-CR-79-28, dated 15 March 1979, was issued following the completion of the Phase I effort. Phase II is being continued under project R78 3121. This technology is being considered by Vought for implementation on the high production volume MLRS. Other systems under consideration include the ROLAND, IMPROVED HAWK, and SAM-D rockets.

MORE INFORMATION

Additional information may be obtained by contacting Mr. William Crownover, Redstone Arsenal, AL, AV 746-5821 or Commercial (205) 876-5821.

Summary Report was prepared by Ron Russell, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project R78 3167 titled, "Production Controls to Prevent Plated Through Hole Cracking," was completed by the US Army Missile Command in December 1980 at a cost of \$223,000.

BACKGROUND

Plated-through-hole (PTH) cracking in multilayer circuit boards is due to 2-axis differential expansion of board laminates and copper plating. This condition often occurs after wave soldering, solder fusing or reflow operations where the board is heated to high temperatures. It is a critical problem affecting board reliability and production yields.

SUMMARY

The project's objective was to correlate optimum copper plating baths and multilayer board (MLB) laminate material which would eliminate PTH cracking. The work was performed by Hughes Aircraft Co., Fullerton, CA, and was divided into three phases.

Phase I examined the physical and chemical characteristics of various acid-copper (sulfate) and alkaline-copper (pyrophosphate) plating systems. Copper foil plated from 10 different baths was tested for percent elongation, ultimate tensile strength, and hardness. Based on this screening, the Sel-Rex sulfate (CUBATH M) was selected as one of two baths for the Phase II production simulation mode. The M&T Chemicals, Inc., pyrophosphate (UNICHROME) with organic additive was chosen as the second bath because of widespread industry usage.

Phase II evaluated MLB laminate materials. A literature search and vendor survey produced three candidates: epoxy-glass; polyimide-glass; and epoxy-polyimide glass (Cor-Lam). Glass transition temperature (T_g) and z-axis expansion data was obtained for all material types in the fully cured (C-stage) condition, and materials were laminated for use in the final Phase.

Phase III developed a simulated production mode with the two previously selected baths by plating a total of 36 MLBs per day (6 of each laminate type) for 10 to 12 weeks. Test coupons from each MLB were subjected to thermal stress tests specified in MIL-P-55640 and MIL-P-55110C (solder float at 550°F for 10 seconds). They were then microsectioned and examined for cracks. A formalized bath qualification procedure that significantly reduced PTH fractures was established. Test data was analyzed, tabulated and used to determine the best combination MLB laminate material and copper plating bath. Tests on copper foil plated by the ten baths indicated that the Sel-Rex (CUBATH M) and M&T Chemicals, Inc., (Copper-Lume PC) acid-copper baths produced deposits with the highest ductility. They exhibited 19.6 percent and 16.5 percent elongation, respectively, on baked samples.

The Harshaw Chemical Co., (Cu-TRONIX) acid-copper bath produced deposits with the highest elongation (14 percent) in the as-plated (unbaked) condition. Results confirmed that a 300°F post plating bake for 2 hours increased copper ductility, especially in deposits with organic additives. The laminated board glass transition temperature (Tg) measurement proved a viable method for determining amount of cure of laminate polymerization. Tg measurements for epoxy-glass were 118-125°C, for polyimide glass 240-287°C and for Cor-Lam 154-158°C.

Phase III tests determined that there were no cracks in the copper PTHs of polyimide-glass boards even when plated in a non-qualified bath. Some failures (less than 0.2 percent), however, were observed on epoxy-glass and Cor-Lam boards plated in qualified acid and pyrophosphate copper baths. Many failures were detected in epoxy-glass (10.6 percent) and Cor-Lam (5.6 percent) boards plated in a non-qualified acid-copper bath. Polyimide-glass was proven the best MLB laminate material tested. A brief evaluation of a spiral Contractometer and a cyclic Voltammeter showed promise for monitoring the copper bath organic additive concentration.

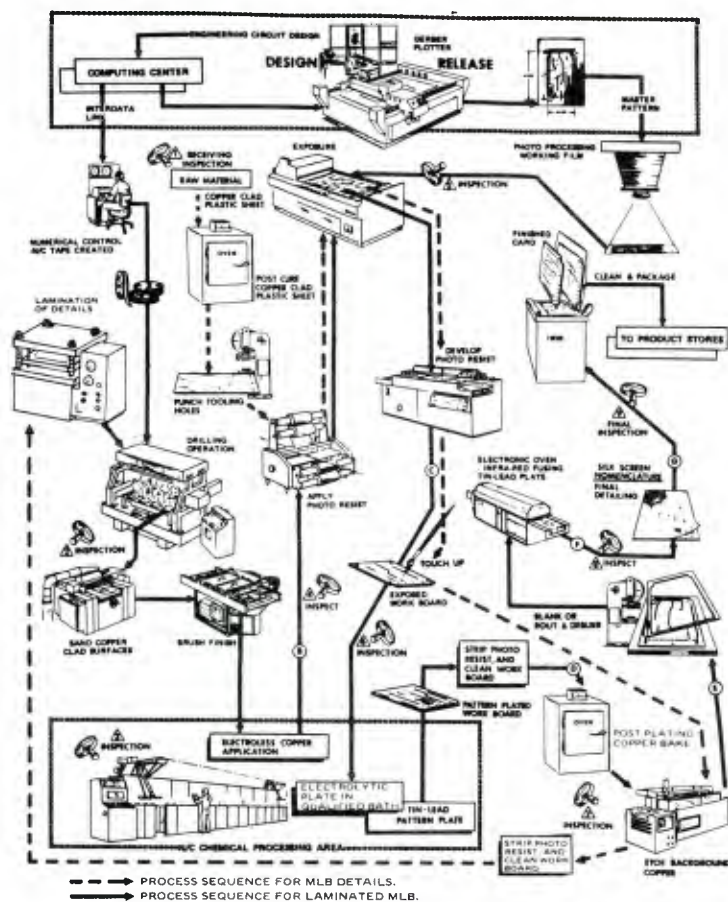


Figure I - MLB Fabrication Cycle

It was concluded that the optimum combination to insure crack-free copper PTHs is a polyimide glass board plated in either the Sel-Rex sulfate (CUBATH M) or M&T Chemicals, Inc., pyrophosphate (UNICHROME) bath and baked to improve copper ductility. A simplified schematic of the complete MLB fabrication cycle is shown in Figure 1.

BENEFITS

The benefits achieved from this effort will enable large scale production of multilayer boards without plated through hole cracking.

The elimination of this defect will result in significant cost savings throughout the electronics industry.

IMPLEMENTATION

The resultant processes, controls and equipment needed to produce crack free PTHs were documented in the final contractor report. This report was distributed to both industry and government.

Hughes has implemented the Sel-Rex sulfate acid-copper plating bath in their board production at the Ground Systems Group, Fullerton, CA.

MORE INFORMATION

Additional information may be obtained from Mr. Lloyd L. Woodham, US Army, MICOM, Redstone Arsenal, AL, AV 746-1572 or Commercial (205) 876-1572. The contract was DAAK40-78-C-0308.

Summary Report was prepared by Stephen C. Yedinak, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects T73 4548 and T74 4548 titled, "Processing ESR Steel for Improved Homogeneous Armor," were completed by TACOM in August 1978 at costs of \$180,000 and \$510,000, respectively.

BACKGROUND

The Army Materials and Mechanics Research Center had maintained a continued interest in the electroslag remelting (ESR) process due to its potential for producing improved homogeneous steel armor. However, the capability in this country for producing large slab ingots, suitable for armor plate fabrication, did not exist until the installation of a large ESR furnace by Lukens Steel Company.

Initial funds were obtained from XM-1 PM Office for an ESR armor plate study. The program involved testing ESR plates of various compositions at different hardness levels to determine optimum chemistry and hardness of advanced armor.

The MM&T program was then initiated to establish an industrial capability for producing ESR armor. Concurrently, plate already produced for the XM-1 program was submitted to TECOM for proof testing. The MM&T program was designed to enhance the capability at Lukens to produce ESR armor plate by providing a low-temperature tempering furnace for large size plates. Contract negotiations were initiated with Lukens for an effort which would have provided the required equipment. A substantial quantity of armor plate was also to be produced and evaluated under the same contract. The large funding (\$365,000) estimated to perform the contract necessitated a lengthy negotiating period.

During this negotiating phase, the program encountered two serious setbacks. The ESR armor plate produced under the prior program was plate proof tested at TECOM. Although the testing showed favorable material behavior at ambient temperatures, low temperature testing exposed a serious toughness deficiency. Extensive plate fracture occurred on the majority of impacts, thereby rendering the initially selected alloys virtually unacceptable. The second difficulty arose when Lukens Steel Company severed contract negotiations with AMMRC on the MM&T program due to other marketing priorities. Thus, two years after AMMRC had begun evaluating ESR armor plate and after AMMRC had received MM&T funds for producing ESR armor plate, the program and the ESR materials previously committed for evaluation were found to be deficient.

SUMMARY

Rather than abandoning the program, TACOM chose to carry out the general objectives of establishing an industrial capability for processing ESR armor plate.

The major objectives in order of their completion were as follows: (1) Jessop Steel Co. - ESR processing, ie, rolling, heat-treating and flattening technique development, (2) FMC Corp. - ESR Armor Fabrication, ie, simple and offset forming in the mill-hardened condition, (3) AMMRC - Optimization of ESR Armor for improved low-temperature toughness. A "rule of thumb" technical objective was to achieve a hardness in excess of 50 HRC and charpy impact of 20ft-lb. plus at -40°F. Table 1 outlines the properties achieved in which ingot number 14 exceeded the planned objectives.

Table 1 - Selected Properties of ESR Ingots Produced at AMMRC for Improved Low Temperature Toughness

Ingot	Chemistry	Hardness (HRC)*	Charpy Impact+ (ft-lb (-40°F))	V ₅₀ B.L. (fps) 14.5-mm BS-41
ESR-1	4335	53.7	16.5	2488
ESR-5	4337 - 0.5 Mo	55.0	15.2	2399
ESR-6	4337 - 2.25 Si	46.1	10.0	2251
ESR-7	4340	56.5	14.2	2333
ESR-8	4340 - 3 Ni	55.9	15.5	2346
ESR-9	4340 - 3 Ni + 0.5 Mo	56.0	15.5	2336
ESR-11	4339 - 3 Ni	55.0	14.9	2356
ESR-12	4336 - 3 Ni + 0.5 Mo	55.2	17.8	2206
ESR-14	4331 - 3 Ni	51.8	22.9	2429

*Tempered 325°F

+ESR-1 to ESR-12 each, one test

ESR-14, average of 6 tests

BENEFITS

Beneficial results of this effort are as follows:

1. A capability for producing ESR armor plate was established.
2. Secondary fabrication of heat-treated ESR armor was demonstrated. Simple and offset bends were successfully accomplished on plate hardened in excess of 500 Bhn.
3. An engineering study was performed which defined facility requirements for establishing ESR capability in an existing steel mill.
4. A production crucible capable of making ESR slab ingots weighing 5,000 to 10,000 pounds was manufactured.
5. An optimized ESR armor alloy with improved low-temperature toughness was produced and evaluated.
6. Data generated in this program were used to draft an ESR armor specification. The draft was finalized and distributed as specification MIL-A-46137MR.

IMPLEMENTATION

The military specification MIL-A-46137MR was established and distributed. The final technical report, AMMRC SP 78-4, has been published. Program Managers of SML, IFV, AAH, and UTTAS were given briefings.

MORE INFORMATION

Additional information may be obtained by contacting Mr. Samuel Goodman at TACOM, AV 786-5814 or Commercial (313) 574-5814.

Summary Report was prepared by Ken C. Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects T77 5083 and T78 5083 titled, "Upscaling of Powder Metallurgy Processes," were completed by the US Army Tank Automotive Command in August 1980 at costs of \$215,000 and \$293,000, respectively.

BACKGROUND

Prior MM&T projects had demonstrated the economic advantages of powder metallurgy processes for small components. One project had successfully demonstrated the economics of the powder metallurgy process for producing small pinions and idler gears used in a differential of a 1/4 ton truck. This project was undertaken to demonstrate that these powder metallurgy processes could be applied to much larger gears.

RESULTS

Both projects were undertaken to demonstrate that isothermal forging of powder metal preforms could produce spur gears. The first year's effort applied this process to the final drive pinion of the M60 Tank.

This gear has a plan area of 15 square inches and represents the first stage in scaling-up this process. The second year's effort applied this process to the final drive gear of the M60 Tank. It has a plan area of 1,170 square inches and represents a major step in scaling-up this process.

Isothermal forging is a forging process where the die is heated to the same temperature as the material to be forged. For steel, this temperature is in the range of 1450° to 1750°F. Keeping the work piece and die at the same temperature minimizes die chilling effects and allows greater detail to be obtained in the forging. The dimensional goals set for forging both gears were to obtain forged gear teeth that would require only final grinding operations. Obtaining these dimensional goals would mean the elimination of machining operations required to cut the teeth and would be the major contributor in generating the savings.

Work was initiated first on the smaller gear so that lessons learned from this gear could be applied to the larger gear. Powder metal preforms and the die system were designed and fabricated for the smaller gear. Forging trials were initiated. A problem of ejecting the forging from the die was encountered during these trials. The forgings tended to stick in the die and no satisfactory lubricant could be found to ease this tendency. Thus, the work on isothermal forging of powder metal preforms was halted. The program objectives were then reassessed and another approach was recommended. This approach consisted of using conventional forging techniques rather than isothermal techniques. This approach was the same one used to successfully produce the pinion and idler differential

gears for the 1/4 ton truck. In a follow-on FY79 effort, the conventional forging of powder metal preforms will be scaled-up and applied to accessory gears in the Abrahms Tank.

BENEFITS

The efforts in FY77 and FY78 were technically unsuccessful. The FY79 effort has been redirected towards the scale-up of conventional forging of powder metal preforms as applied to accessory gears of the Abrahms Tank.

IMPLEMENTATION

Since the results to date have been unsuccessful, no implementation has taken place.

MORE INFORMATION

Additional information may be obtained from Mr. Donald Ostberg, TACOM, Attn: DRSTA-, Warren, MI, AV 786-1814 or Commercial (313) 573-1814.

The following technical reports have been prepared:

"Forging of Powder Metallurgy Gears," Final Report on the FY77 effort and Contract DAAK-30-78-C-0029, Report 12517, May 1980.

"Isothermal Forging of Forge Gears by P/M Techniques," Final Report on the FY78 effort and Contract DAAK-30-78-C-0099, Report 12521, May 1980.

Summary Report was prepared by Gordon Ney, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project T77 5085 titled, "Production Techniques for Fabrication of Turbine Engine Recuperator," was completed by US Army Tank Automotive R&D Command in February 1979 at a cost of \$400,000.

BACKGROUND

Avco Lycoming's AGT 1500 gas turbine, selected to power the XM-1 Tank, is a recuperative engine with a multiwave plate recuperator of advanced design. This recuperator is a thin plate heat exchanger made by welding together about 580 convoluted plates, each .008-inches thick. There are over 10,000 feet of weld joining the plates; so improved, higher speed welding techniques would offer significant cost reduction opportunities. The fabrication of a recuperator core basically involves preparation of details, joining of the details, and pressure testing. During the early development phases of recuperator core design and fabrication, various joining processes were considered. Among these were several welding techniques such as inert gas-tungsten arc, plasma arc, and electron beam welding. The results of tests of these processes using subsized specimens showed problems with each. Resistance seam welding eliminated the requirement for precision alignment, offered a reliable joining method, and therefore became the standard process.

However, resistance seam welding was also limited by a maximum travel speed of about 50-inches per minute. Subsequent experience had shown that although the resistance seam welding process is satisfactory for the fabrication of plate type recuperators, it requires a large number of welding machines and substantial maintenance support to meet production requirements.

SUMMARY

In order to reduce welding time and cost, a two-phase program of screening and verification testing of various welding techniques was undertaken. The requirements established for the welding process were: (1) low sensitivity to anticipated deviations in fit-up, (2) reliability, and (3) high speed of welding. Laser welding was selected as the most promising technique for accomplishing these improvements. It does not require contacting electrodes as does resistance welding nor vacuum chambers, as does electron beam welding. The laser is also capable of high welding speeds.

Major benefits in applying laser welding can be derived from welding the air inlet and outlet holes alone; since these welds comprise 60% of the total length of the recuperator welding. Because they are short, interrupted welds, with three or four passes per hole, they account for over 75% of the welding process time.

Major effort was therefore concentrated on developing and testing laser welds for the hole peripheries during this Phase I project.

The machine selected for this application was a British Oxygen Corporation 2KW continuous output CO₂ laser with computer controlled moving output mirrors to permit high speed welding of the complex air passage periphery joints. Also designed and built were the output mirror support structure, prototype work handling and welding fixtures and a safety enclosure. Figure 1 shows the laser welding system.

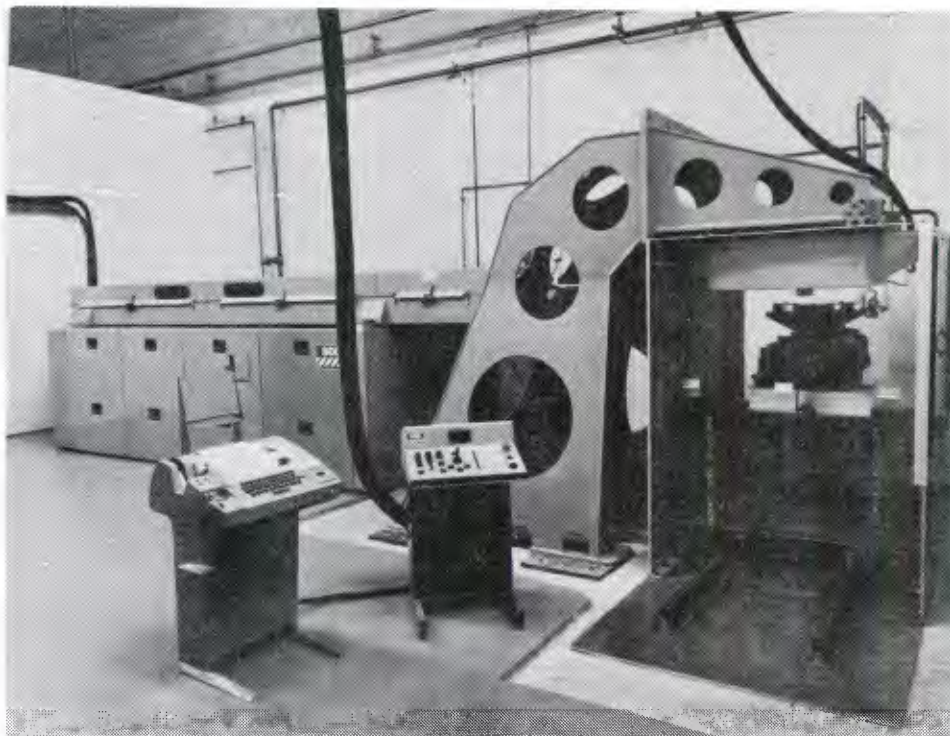


Figure 1 - Laser Welding System

A computer program to weld the air conduit holes at high speed was written. Optimum weld settings were developed and the welds evaluated both destructively and non-destructively. A preliminary investigation showed the low cycle fatigue strength of laser welds to be equal to resistance welds when loaded by internal pressurization at 1300°F, the conditions encountered in service. The optimum setting for welding the recuperator plates was a speed of 250-inches per minute as compared to the average of 50-inches per minute for resistance seam welding. Furthermore, each hole was welded in one continuous pass rather than several passes for each hole as with resistance welding.

Fixturing requirements for laser welding thin plates were also investigated and the optimum methods determined. Prototype tooling using these concepts has been designed and procured. A preliminary cost comparison of laser versus resistance seam welding for the air duct hole welds showed a weld station of two laser welders to be capable of producing parts at the same rate as an eight

machine resistance welding station at significantly less cost. It was concluded that laser welding had the potential for a substantial reduction in recuperator production cost and that work proposed for Phase II should be continued.

BENEFITS

This first year effort developed the most economical joining parameters, an optimized welding station, and established the preliminary tool designs. The project also verified the suitability of laser welding for the recuperator application.

IMPLEMENTATION

The results of this project are implemented in the Phase II Project T78 5085.

MORE INFORMATION

Additional information may be obtained by contacting Mr. S. Goodman, TARADCOM, at AV 786-1814 or Commercial (313) 573-1814.

Summary Report was prepared by Ken Bezaury, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MUNITIONS



IOWA AAP DETONATOR LOADER

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 574 1249 titled, "Advanced Technology for Pyrotechnic Mixtures and Munitions," was completed by the US Army Armament Research and Development Command in January 1975 at a cost of \$830,000.

BACKGROUND

This is the second project of a multi-year effort to eliminate the "black art" from the pyrotechnic smoke munitions manufacturing. Formulation and blending problems with the white smoke mixes were caused by an inadequate specification for the raw materials and the double cone blending process. In addition, the current specifications for the colored smoke mix raw materials were also inadequate resulting in the use of low purity dyes. This caused production problems with controlling the munition burning time which was a basis for acceptance. During the FY73 program, emphasis was on classifying the individual ingredients of white smoke mixes and determining the interrelationship of the physical properties to establish controls on the performance of the resulting pyrotechnic mix. An air-jet mixer was determined as being applicable to the blending of smoke mixes. In addition, studies were initiated on castable colored smoke mixes to determine their process parameters. The FY74 project effort continued the process studies on the white and colored smoke mixes. This total program will provide technical data for modernization of the hexachloroethane (HC) mix facility at Pine Bluff Arsenal and data to establish a castable colored smoke mix facility.

SUMMARY

The objectives of this project were: (1) to completely define the critical parameters of processes used to manufacture standard white pyrotechnic smoke mixtures; (2) to initiate similar efforts for plasticized colored smoke grenade mixtures; and (3) design, pilot and demonstrate a production process for mixing and blending smoke mixes. The project was divided into basically two tasks, White Smoke Mix and Colored Smoke Mix. In the White Smoke task, moisture evaluations, and hexachloroethane/aluminum/zinc oxide blending studies were performed by Pine Bluff Arsenal (PBA). Process studies on colored smoke mixes were conducted by Edgewood Arsenal (EA).

In the white smoke studies, a direct relationship between the relative humidity (RH) during blending and the burn time of HC M8 grenades was established. The grenades were prepared from HC batches blended at RH values of 40% (burn time 120 sec) to 70% (burn time 95 sec). Tests indicated that the optimum RH condition was 50%.

Blending studies evaluated various grades of hexachloroethane and aluminum. All grades of hexachloroethane produced acceptable HC mix as determined by MIL-STD-414. The American First-O-Line hexachloroethane produced what appears (visual observation) to be a denser white smoke than that produced by the Nease or Hummel hexachloroethane. The order of decreasing densities appears to be American First-O-Line, Nease, and Hummel; with no apparent difference between the two grades of Hummel. Four grades of aluminum were evaluated with each grade producing acceptable HC mix (MIL-STD-414).

Blending studies were also conducted on various commercial grades of zinc oxide that had potential use in the HC air-jet blending of HC mix. Blending and characterization studies were completed for ten commercial grades of zinc oxide. Those grades that showed promise were selected for further blending studies with various grades of aluminum and hexachloroethane.

A pilot plant air-jet mixer was installed at Pine Bluff Arsenal. About sixty batches of HC smoke mix were blended and found to be satisfactory. The initial plan was that all of the raw materials were to be gravity fed into the air-jet mixer. However, earlier blending tests indicated the need for preblending the hexachloroethane and zinc oxide to form a premix prior to charging the mixer. As a result, it was decided to offset the premix equipment so that the same equipment could be used to charge more than one air-jet mixer. The concept in Figure 1 shows the use of pneumatic transfer by either vacuum or positive pressure means.

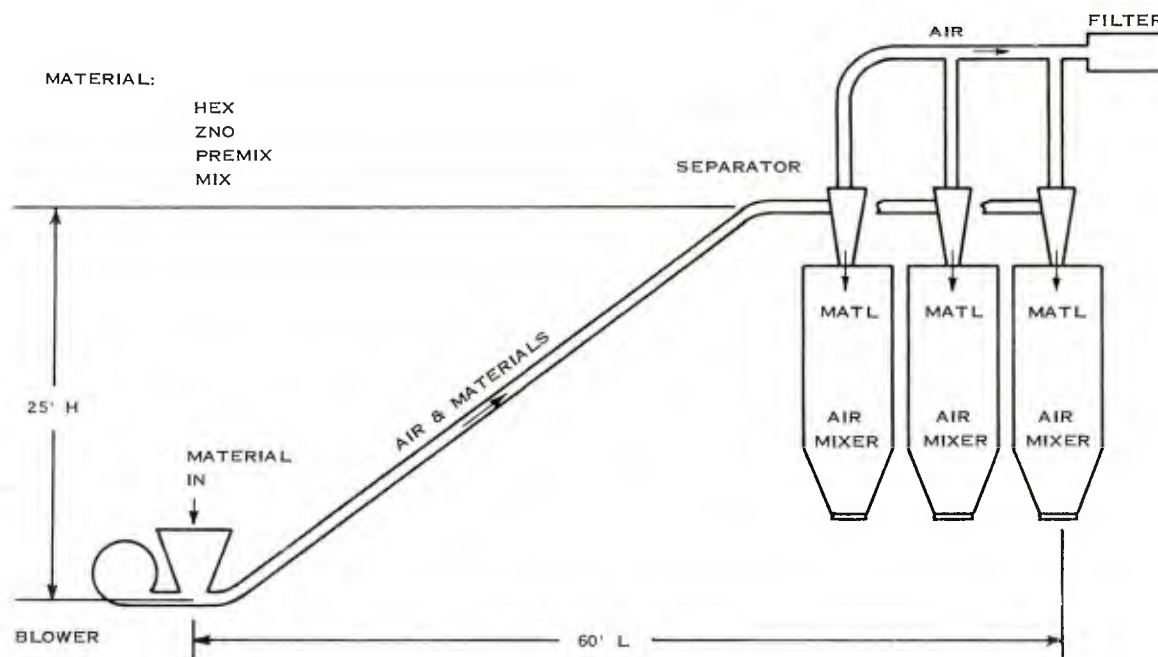


Figure 1 - HC Materials Handling Pneumatic Transfer Configuration Vacuum & Positive

The colored smoke studied originally involved the investigation of castable mixes using a polymer based PBS-5 starter mix and a polymer bonded colored smoke mix. These castable mix studies were terminated because of technical difficulties and increased material costs. The study was redirected to emphasize the use of coarse particle size chemicals and dyes for the fine particle size chemicals and dyes currently used in the standard mix. However, since coarse dyes were not commercially available, a series of pelletization studies were planned to investigate the feasibility of making pellets or tablets. The objective was to compact the dry, dusty, powdery mix into pellets that could be easily loaded in an M18 grenade. This effort was continued in FY75 under MMT 575 1296.

BENEFITS

This project provided the critical parameters for processing smoke mixes which will minimize production mixture quality variances and thus insure improved munition performance. In addition, new process equipment, an air-jet mixer, was used to attain improved blending techniques resulting in reduced cost and minimized safety hazards.

IMPLEMENTATION

Process and blending information was used to upgrade material specifications which will result in a satisfactory premix. Process data on the use of the air-jet mixer to produce HC mix and colored smoke mix will be utilized in the facility modernization projects 576 0265 and 577 0266.

MORE INFORMATION

Additional information on this project is available from Mr. C. Ferret, Chemical System Laboratory, AV 584-3007 or Commercial (301) 671-3007.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 575 1249 titled, "Advanced Technology for Pyrotechnic Mixtures and Munitions," was completed by the US Army Armament Research and Development Command in July 1977 at a cost of \$750,000.

BACKGROUND

This is the third project of a multi-year effort to eliminate the "black art" from pyrotechnic smoke munitions manufacturing. It provided the ground work of technology for future modernization projects and for process engineering efforts in support of product improvement of M8, M18 grenades. Earlier projects (FY73, FY74) evaluated the physical characteristics and processing limits of standard white mix for the M8 grenade and initiated the study of standard and polymer mixes for the M18 colored smoke grenade. Work was initiated on the material handling aspects associated with these processes. This project will complete the blending and material handling tasks, the classification of operating parameters, establish the manufacturing process, and establish design data for modernized facility for M8 and polymer-base M18 grenades.

SUMMARY

The major objective of this study was to better define all materials and processes related to pyrotechnic mixtures as related to white smoke and colored smoke munitions. Pine Bluff Arsenal performed the work on white smoke and the Chemical Systems Laboratory conducted the studies on colored smoke mixes.

WHITE SMOKE - These studies involved completing the work on three tasks: (1) the smoke mix blending process; (2) the material handling equipment; and (3) establish physical and chemical parameters for the white smoke raw materials.

The blending process for hexachloroethane (HC) white smoke was piloted and scaled up at Pine Bluff Arsenal (PBA). The concept utilized a premix step to equilibrate the raw materials (zinc oxide and hexachloroethane) with a controlled 50 percent relative humidity, and a jet air blender to uniformly blend the premix with aluminum. The jet air blender utilized a high pressure (250 psig) and high volume air flow to blend a 2200 pound batch in 48 seconds. The blender, which contained no moving parts, in contact with the material was classified as a safe operation based on test results from NASA Test Center, Bay St. Louis, Mississippi.

A material handling system was selected and built for the transfer of hexachloroethane and zinc oxide. The materials handling system utilized a positive pressure, low velocity, dense phase transfer technique. The system was piloted at PBA and the results were included in the design of the HC mix facility modernization (project 576 0265).

The optimum chemical and physical characteristics were identified for the HC raw materials (hexachloroethane, zinc oxide, and aluminum) that were compatible with blending and material handling process. Specification changes reflecting these optimum characteristics were accomplished. Based on chemical and physical tests of the raw materials, mass flow hoppers were designed for each raw material and included in the plant design for the new HC mix facility.

COLORED SMOKE - This work was initiated to complete the pelletization and granulation ingredient studies as related to the use of coarse raw materials.

The utilization of coarse chemicals and dyes in the M18 colored smoke grenades was evaluated. The use of coarse materials offered many advantages over standard fine particle size ingredients. These were: (1) a lower price of chemicals because the coarse materials were mass produced for other industrial uses; (2) would cause less dusting during handling and pressing operations; (3) eliminated the need for kerosene or acetone that is added to the standard fine ingredients to reduce dusting during handling and pressing the mix.

Since coarse dyes were not commercially available, a series of pelletization studies was conducted with red smoke mixes to determine the feasibility of making tablets or pellets. Such pellets were produced using a Stokes Model F and Model BB-2 tableting machines. Pellets were successfully produced; however, an analysis of costs to procure and operate the pelletizing machines showed it to be an uneconomical approach. Therefore, a study was initiated to evaluate two types of processes to granulate the dyes. One involved a multistage machine called a Chilsonator that recycles material to achieve granulation. The first stage of the Chilsonator was the compaction station. The dye moved from a storage hopper by means of a screw feed into the compaction rollers. Two steel rollers rotating in opposite directions compacted the dye into thin corrugated sheets. In the second stage of the Chilsonator, these sheets were broken up into granules by a comminuting mill. The granules then fell into the third stage of the Chilsonator where they were sized. A vibrating screen separated the dye into three size increments: product size, oversize, and undersize. The product-size material (i.e., material of the desired size) was discharged into a collection vessel. The oversized granules were recycled through the comminuting mill for regrinding, and the undersized material (fines) recycled through the compacting rollers.

The second process investigated was the Glatt granulator. In this process, a dye with dextrin added according to specification was placed in the processing chamber of the Glatt granulator. Air was forced in at the bottom of the processing chamber, and the dye was fluidized and mixed. While the dye was being fluidized, a fine mist of water was sprayed onto the powder. The water-soluble dextrin (an added diluent allowed by the dye specifications) acted as a binder, and dye granules began to stick together and to grow. The size of the granules was controlled primarily by the quantity of water added and the cycle time. When the dye granules were of the required size, hot air was introduced into the chamber and the granules were dried (while being fluidized). Both the Chilsonator and the Glatt granulation processes demonstrated their capability of agglomerating fine particle size dyes to the coarse particle size required.

Experimental tests were then conducted to determine the formula needed to meet the performance criteria. The optimum blend was then selected and larger batches were prepared for loading into grenades. Acceptability tests, composed of functional

and hazard classification tests were performed on the grenade formulated with the granulated materials. A total of 1200 grenades were produced and results indicated that there was little difference between the experimental coarse material grenades and the standard M18 grenades.

BENEFITS

This project improved the producibility of the AN-M8 and the M18 grenades. It provided technical information which will improve the quality of the grenades, reduce production costs, and increase safety. In addition, the technical data package was updated to make it possible for commercial producers to produce a better product at a lower cost.

The cost reductions associated with the AN-M8 amount to \$.082 per lb of HC mix produced. Cost reductions on the M18 grenade are as follows: red - \$.35/grenade; violet - \$.26/grenade; green - \$.30/grenade; yellow - \$.41/grenade.

IMPLEMENTATION

The HC blending and material handling process identified was incorporated into the design for modernization of HC mix facility at PBA. The design was completed and a contract issued to modernize the building and install the process equipment. The facility was completed in March 1978.

Specification changes were requested and approved by the Configuration Control Board for hexachloroethane, zinc oxide, and aluminum reflecting the optimum chemical and physical properties identified.

MORE INFORMATION

Additional information on this project is available from Mr. C. Ferret, Chemical Systems Laboratory, AV 584-3007 or Commercial (301) 671-3007.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 575 4032 and 576 4032 titled, "Automated Equipment for Assembly of M737 Fuze," were completed by the US Army Armament Research and Development Command in December 1978 at costs of \$750K and \$615K, respectively.

BACKGROUND

The M557 and M572 Fuzes had been standard for many years; however, the design demanded manual assembly operations.

The M739 Fuze replaced both the M557 and M572 and was designed specifically for automatic assembly to provide a high quality, low cost device to overcome the problems encountered in the manually-assembled fuze. Under a previous Production Engineering and Product Improvement Program, ten automatic assembly machines were fabricated. Under this program, these ten machines were modified and updated for piece-part configuration changes and improved machine performance. Four new machines were designed and built to complete the prototype assembly line.

SUMMARY

The objective of this project was to complete an automated production line for assembly of the M739 Fuze (Figure 1). The line was developed in modules, keeping the machines simple, striving for a low downtime rate. To accomplish this, the fuze design was broken down into subassemblies that were as simple as possible, thereby simplifying the assembly operation of each machine. The concept resulted in small, severable and non-synchronous machines with maximum flexibility for mobility.



Figure 1 - M739 Fuze

The operations of the machines included feeding of fuze components, verifying the presence and position of the components, pressing and staking of components and testing. Through lock-out and memory features, the quality of subassemblies was continuously monitored and sorted as acceptable or unacceptable. Maximum use of bulk storage and feeding methods were employed; however, magazines were used when parts or subassemblies were fragile or difficult to orient.

BENEFITS

Benefits include a decrease in cost, a decrease in requirements for large numbers of extensively trained and skilled operators and inspectors, a decrease in floor space requirements and a reduction in material handling.

A complete set of tooling drawings was prepared for each machine making it possible to duplicate the line.

IMPLEMENTATION

All the machines were installed at the Twin Cities Army Ammunition Plant. The success of the line was demonstrated by the assembly of over two million M739 Fuzes with no machine related difficulties. As a result of the success of this project, another group of machines is being built to yield an output of one million fuzes per month.

MORE INFORMATION

Additional information and a copy of the final report, "Design and Manufacture of Automated Tooling For Assembly of Fuze, PD M739 Less Booster Pellet," is available from Mr. Emil Babich, ARRADCOM, Autovon 880-3153 or Commercial (201) 328-3153.

Summary Report was prepared by James H. Sullivan, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 572 4144 and 573 4144 titled, "Bulk Handling of High Explosives," were completed by the US Army Armament Research and Development Command in May 1976 at costs of \$500,000 and \$462,000, respectively.

BACKGROUND

This effort was to establish the feasibility of pneumatic conveying, bulk handling and shipping, automatic box filling and bulk rail/truck transport system. The project was for the design, installation and operation of a prototype system for packaging, handling and shipping TNT in bulk quantities. The effort was to investigate pneumatic conveyors, mechanical conveyors, bulk containers, bulk TNT railroad car/truck transport, and a conveyor system for unitized bulk load.

SUMMARY

A decision risk analysis was performed on the bulk handling concept planned at Volunteer AAP; specifically, the pneumatic conveying of flake TNT from six production lines to a central packaging building from which bulk bins and palletized boxes were to be transported to a car/trailer loading dock where they would be handled by fork trucks.

As a result of the initial phase of the decision risk analysis, it was decided to concentrate efforts on the unloading of bins under adverse conditions, i.e., when the TNT is caked. The problem was complicated by the possibility that the bins might be filled from the flaker in a finishing building or from a pneumatic conveyor.

Attempts to remove freshly flaked TNT from bins stored at 130°F for seven or more days (to simulate shipping conditions which may be encountered) were not successful. Vibrators were strapped to the bin and operated at various frequencies, developing rated forces of up to 4000 pounds. Vibration was alternated with rotation of the bin. In most cases, less than one percent of the TNT was removed. In one case, a four-inch long crack occurred in the wall of the bin. This was a hazard in that the crack could be a point of initiation. No further work was done with vibrators. Six bins were filled with freshly flaked TNT and stored in a magazine at 60°F. They were emptied at approximately weekly intervals. In each case, a friable lump was present in the center. After three weeks storage, it was necessary to invert the bin several times to remove all the TNT. A bin containing 3500 pounds of Comp B was heated 21 days at 130°F. The Comp B was free flowing except for an 18-inch friable lump in the center.

Samples of caked TNT were subjected to compression testing. In general, after similar heat treatment, pneumatically conveyed TNT formed lumps which were more than twice as strong in compression as lumps of unconveyed flake TNT.

Standard shipping boxes containing 55 pounds of pneumatically conveyed and unconveyed TNT were stacked 10 high in the 130°F oven. The conveyed TNT shows a greater tendency to cake. Compressive strength of the caked samples was comparable to that found in bins.

It became apparent that a considerable effort was still required to understand the phenomena associated with caking of TNT sufficiently to design practical systems for reliably unloading large containers of TNT.

TNT produced by the continuous process at Radford AAP and pneumatically conveyed during extended runs at Volunteer AAP were sent to user plants for evaluation; almost 400,000 pounds to Louisiana AAP and 50,000 pounds to Holston AAP. In both cases, dust levels were significantly higher than usual because of the fine dust in the pneumatically conveyed TNT. At Louisiana, the melt cycle was slightly reduced. No difficulty was encountered in pouring. At Holston, melting time was increased about 10 percent even with increased agitation. Only minor changes in the system were anticipated at Louisiana in order to accommodate pneumatically conveyed TNT, while Holston anticipated extensive redesign.

During extended test runs of the pneumatic conveyor system, a dense glaze coating of TNT was found on the wall of the cyclone. A less dense coating in the elbows and wall of the 6-inch pipe line was also found.

This effort surfaced several problems with the bulk handling of high explosives. The problems included: (1) pneumatic conveying of freshly flaked TNT resulted in the formation of coatings on the walls of the conveyor pipe and collecting cyclone. In addition, the particle size of the TNT was reduced to the point where handling at the user plant could be a problem; (2) filling of bulk bins with freshly flaked TNT and storage at temperatures which might occur in box cars resulted in cakes which were difficult to remove; and (3) automated box filling was found to be uneconomical when applied to TNT producer plant.

BENEFITS

It was learned that the physical characteristics of TNT would prevent using pneumatic conveyors to transfer flake TNT and that TNT could not be recovered efficiently from bulk storage bins.

IMPLEMENTATION

Partial application of the technology developed under this effort included the following: (1) an automated mechanical conveyor was installed in the prototype continuous Comp B line at Holston AAP, Kingsport, Tennessee; (2) mechanical

conveyors were installed in the prototype LAP line at Lone Star AAP; (3) it is planned to install automated packaging systems in the modernized facility for making RDX, HMX and Comp B.

MORE INFORMATION

Additional information may be obtained from Mr. Albin Litty, ARRADCOM, AV 880-4496 or Commercial (201) 328-4496.

Summary Report was prepared by Jim Bruen, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 576 4211 titled, "Modernization of Process Control of Explosive Compositions," was completed by the US Army Armament Research and Development Command in February 1979 at a cost of \$175,000.

BACKGROUND

Rapid and accurate instrumental process analyzers that measure explosive control parameters during processing and loading of ammunition items are considered a necessary phase in the modernization of ammunition manufacture. No process can be automated without sufficient automatic means with which to measure and control process parameters required to maintain process integrity. Parameters such as temperature, pressure, flow rate, level, chemical composition and phase segregation are only some of the types that must continually be controlled, otherwise the process goes beyond specified limits resulting in either a dangerous condition or the production of an unsuitable product. Systems that can measure and control temperature and pressure in an explosive process are readily available off-the-shelf. On the other hand, instruments which measure and control process parameters such as flow rates, densities, fluid levels, and compositions in formulation and loading processes are not available off-the-shelf. These types of instruments must be designed and developed for each specific application. As an example, explosive compositions are currently processed while the in-process control is maintained on the basis of laboratory analysis which cannot be completed within a realistic time frame. New technologies needed to be explored for development of prototype analyzer systems that can be installed in the new modernized continuous processes developed for compounding and melt loading Comp B, Cyclotols and Octols.

Another difficulty in explosive production is the characterization of explosive materials by citing tolerances for physical properties (e.g. viscosity, particle size). Sensitivity is an explosive characteristic which is an important measure of the general safety of the explosive. Therefore, in order to assure the continuing quality of explosives produced, efforts were planned at automating the impact sensitivity test. This would provide more accurate and precise data for the accept/reject criterion of explosives.

SUMMARY

This project involved two objectives. The first was to design and develop instrumentation to measure the composition, flow and level in processes where molten explosives are compounded and loaded. The second was to design and develop

an automated impact tester to determine the sensitivity of explosives. This second objective was to be addressed in the follow-on project.

To attain the objectives in the first task, the potential techniques for controlling and measuring flow rates, levels, and compositions were surveyed. After determining the most feasible techniques, the equipment was procured and installed on-line for evaluation.

Concepts for a non-contact type molten explosives flow measurement system were investigated for application to the melt-pour processes. Dielectric noise and neutron activation were identified as potential concepts. The neutron activation concept was selected for further investigation since it was more advanced and realistic based on available information. However, based on safety problems and equipment costs, a managerial decision was made to suspend further efforts on this task.

In the area of composition analysis, several techniques were considered for analysis of RDX/TNT compositions produced in the Composition B process. They were gamma-ray attenuation, fiber optics, neutron activation, dielectric constant, and x-ray attenuation. As a result of the investigation, the gamma-ray technique was selected for design and prototype construction. A diagram of the RDX/TNT analyzer system is shown in Figure 1.

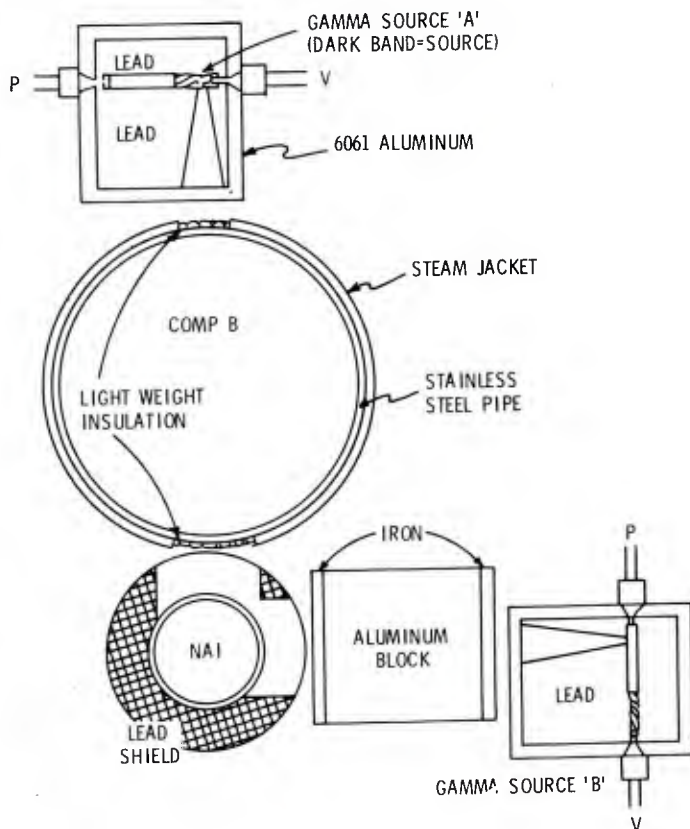


Figure 1 -
RDX/TNT Analyzer System

In the prototype design, the Ba 133 source of gamma radiation was mounted on one side of the steam jacketed chamber containing the molten composition B. Opposite the source, a NaI scintillation detector was mounted for measurements. Lead shielding was used around both the source and the detector to improve the systems stability. A second gamma source B was used to monitor any background radiation.

The composition analyzer system was designed and constructed by Science Application, Inc. The system was then debugged and shipped to ARRADCOM for installation and testing at the continuous melt pour pilot plant. This effort was continued under the FY77 project.

For molten explosive level measurement, a fluidic level control system was designed, fabricated, and tested. The system consisted of a force balance pressure transmitter which was submersible. Head pressure changes were used to detect level changes. The system had a sensitivity of 0.05-inches and an operating range of -40° to 350° F. The system was installed in the ARRADCOM melt pour pilot plant and performed satisfactorily.

BENEFITS

A composition analyzer system and an automatic level control system were designed and developed for processing and loading molten explosives. Use of these systems will reduce operator exposure to process hazards and maintain process integrity.

IMPLEMENTATION

The level control system is an integral part of the ARRADCOM melt pour pilot plant. The composition analyzer will be evaluated in the melt pour pilot plant under the FY77 project.

MORE INFORMATION

Additional information may be obtained from Mr. C. McIntosh, ARRADCOM, AV 880-4123, or Commercial (201) 328-4123.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 573 4218, 574 4218, and 575 4218 titled, "Modernization of Materials Handling at LAP Facilities," were completed in November 1977 by the US Army Armament Research and Development Command at costs of \$745,000, \$213,000, and \$772,000, respectively.

BACKGROUND

In August 1970, the Kaiser Engineers, Division of Henry J. Kaiser Company, released a 28-volume Modernization Engineering Report on the Army's GOCO ammunition plants. It recommended that detailed investigations of the plants be made to establish progressive modernization plans for material handling and storage systems. Subsequently, a five-year MM&T program was established to review and recommend improved materials handling concepts at approximately 70 production lines in 11 Load, Assemble and Pack (LAP) plants. The engineering results of MM&T projects 571 4218 and 572 4218 have been previously reported. This summary report covers the final three years of the five-year MM&T program.

SUMMARY

During FY73 and FY74, an engineering review of materials handling at Lone Star, Longhorn, and Louisiana AAP's was conducted on a total plant basis. The contracted program encompassed the storage of all incoming and outgoing materials as well as centralized warehousing and modern distribution concepts. In addition, concepts were established for the modernization of on-line handling for twenty-one production lines not covered by previous reviews. Typical areas considered for improvement included handling methods, packaging, equipment and facilities. Recommendations from this review were categorized into three classifications which usually were based upon the amount of change that would be required to the existing structures. The categories were:

1. Improvement of present methods within the constraints of existing buildings.
2. Mechanized or partially automated system with minor modification to existing facilities.
3. Mechanized or fully automated system with new facilities or major modifications to existing facilities.

For example, recommended concepts for a centralized storage facility were prepared for each plant with an analysis of pay back ratios. Alternate recommendations were also made for materials handling concepts applicable to existing production areas.

The FY75 project covered similar engineering reviews of materials handling at Kansas, Joliet, and Indiana AAP's. Figure 1 is a concept proposal for a typical effort at Indiana AAP. This automatic concept would eliminate the present manual handling and transfer of propellant-filled drums from a second floor elevator. Such modernization concepts were discussed with each plant before a Phase II final technical report was published.

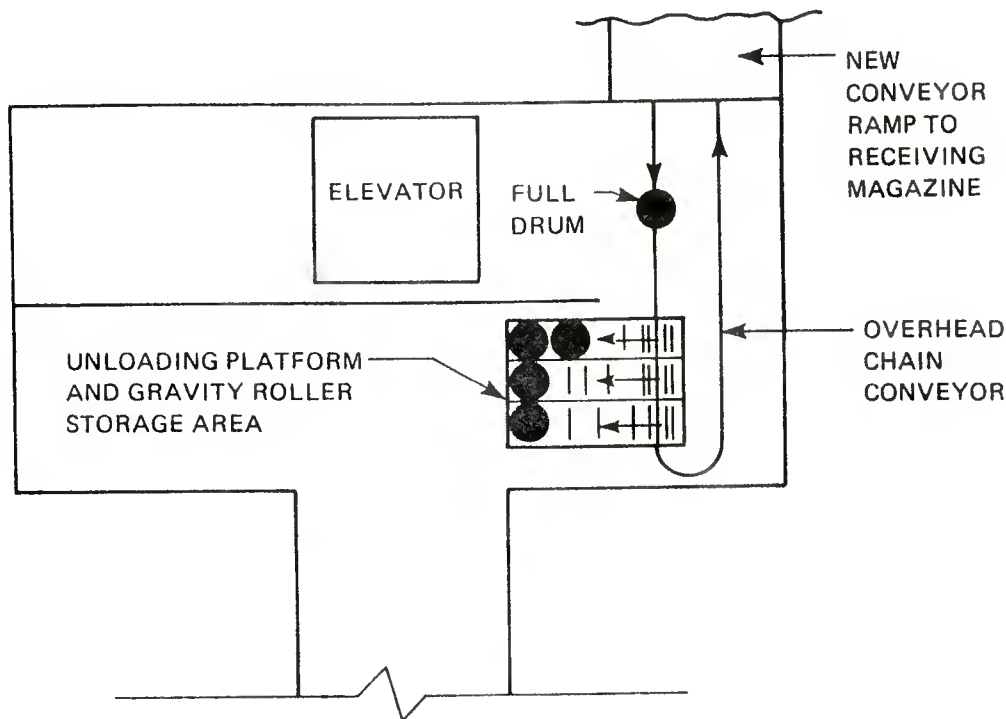


Figure 1 - Second Floor Layout of Conveyor and Unloading Platform

At Louisiana AAP, materials handling of the 155mm projectile on Y Line was investigated. For Lone Star AAP, bid packages were reviewed on the materials handling system for the new 105mm metal parts facility. For Hq, DA, a special off-shore review was conducted on conventional ammunition, handling techniques, and storage.

BENEFITS

The contracted reviews of materials handling at selected GOCO ammunition plants furnished technical data and recommendations for production and warehousing improvements. Timely information on up-to-date methods, equipment and facilities became available for plant modernization and expansion projects submitted during the 1970's and planned for the 1980's.

IMPLEMENTATION

Each plant surveyed received copies of the report which analyzed local materials handling capabilities and modernization needs. Each plant was to implement any acceptable recommendations as part of future facilitation or annual support projects. Indiana AAP is implementing the concept of a tote box storage system for igniter assemblies under an expansion project 580 2694. Plans have also been proposed to adopt a palletainer concept for shipping containers.

MORE INFORMATION

Additional information on these projects can be obtained from Mr. John Mola, ARRADCOM, AV 880-3320 or Commercial (201) 328-3320. Each reviewed plant received Phase I and Phase II technical reports.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 57T 4249 and 578 4249 titled, "Separation of Fine Explosives From Spent Acid and/or Water Slurries," was completed by the US Army Armament Research and Development Command in December 1980 at a cost of \$350,000 and \$460,000, respectively.

BACKGROUND

One of the major problems in the production of HMX at Holston AAP has been the washing, filtering and separation of fine particles from spent acid or water slurries. During FY74 and FY75, various separation techniques were evaluated and tested. These were traveling belt filtering, counter-current leaching, dense phase extraction, use of hydrocyclones and inertial filters. A detailed analysis of the techniques resulted in the selection of a horizontal belt filter called the Bird-Pannevis filter.

SUMMARY

The purpose of this effort was to procure, install and evaluate the Bird-Pannevis horizontal belt filter. Filtering of crude RDX, crude HMX, class 5 RDX/HMX and 80 screen HMX were to be evaluated.

The Bird-Pannevis filter was procured and installed in Building E-4 at Holston AAP in May 1980. A diagram of a Bird-Pannevis Filter is shown in Figure 1. The slurry was gravity fed to the filter counter to the direction of belt travel via a fishtail chute. The endless filter cloth was formed into the reciprocating vacuum tray by a stationary forming bar. The sides of the vacuum tray were designed in such a way that an excellent vacuum seal was maintained between the cloth and the tray wall. Integral compartments were fabricated into the tray to provide near absolute separation of filtrate from wash liquors. The cloth was supported in each compartment by removable molded plastic support grids which simultaneously provided a flat surface for even cake formation.

The operation of the filter was cyclic with vacuum being applied during the forward stroke only. At the end of the forward stroke, vacuum was released and the cloth sprung slightly to minimize friction while the tray returned to the initial starting position. The vacuum was released by a dual control valve manifold where one valve closed on the main vacuum supply and a second valve opened after a pre-set time delay to vent the tray. The cloth speed was variable and synchronized with the forward speed of the vacuum tray. Motive power for the tray was supplied by a stationary double acting pneumatic ram. The tray was supported on a series of

wheels which rode on a dual track system. Time delays, tray forward speed, tray return speed and safety interlocks were controlled by pneumatic logic circuits in the central control panel.

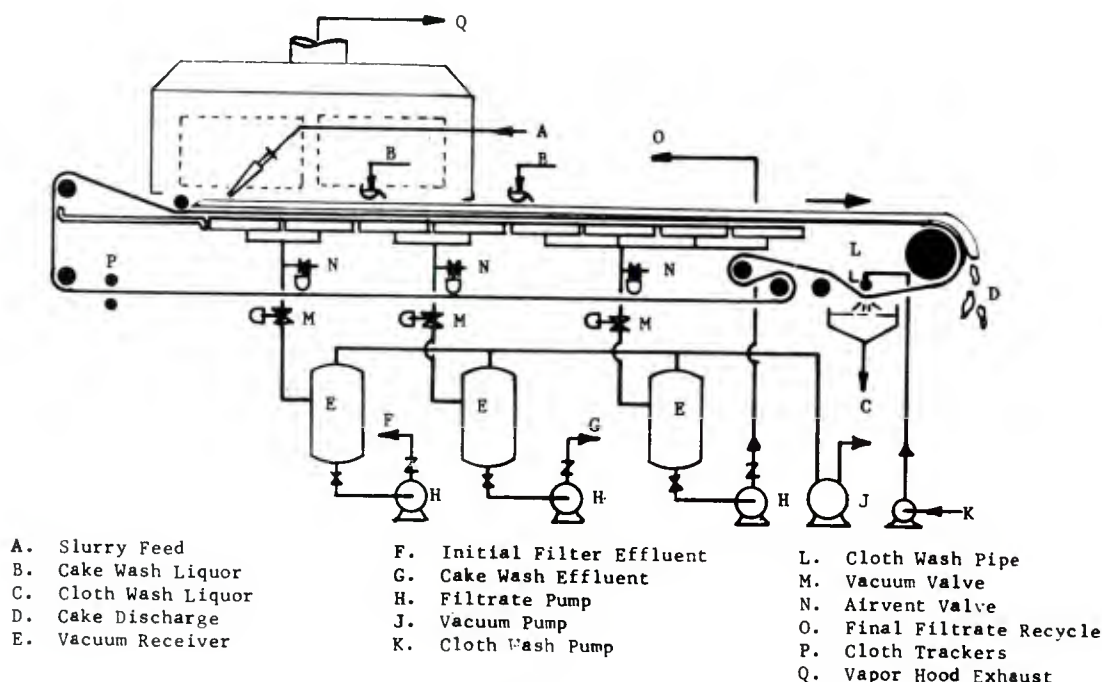


Figure 1 - Schematic Diagram of a Bird-Pannevis Filter Installation (Filter Length is 5.6 meters)

Cake washing could be either conventional displacement washing or counter-current displace wash as needed. Wash liquor could be applied to the cake by either overflow wier type or low velocity spray type wash bars. Washed cake was removed from the discharge by combined cloth flexing and the application of an adjustable, low friction doctor blade at the drive roll.

Production operations were initiated in July 1980 utilizing the new filter system. A decision was then made to evaluate only crude HMX slurries since prior experience indicated the HMX slurries were the most difficult to filter. In addition, only enough funds were available to test one type of slurry. Serious problems were encountered with filter cloth blinding, line coating and valve diaphragm failure when processing crude HMX slurries. Processing techniques were adjusted to minimize these problems where possible, and procurement of butterfly valves to eliminate the diaphragm problem was expedited.

Laboratory testing of two new filter cloths indicated that they should provide better filtration and cleanup characteristics than the cloth in use. Two filter cloths from each weave were ordered for evaluation on the filter. One of the new cloths was installed and reduced filtration time by 12 percent. Cake release

characteristics were improved and cloth stretching was reduced. Butterfly valves were installed to replace the diaphragm valves that were a continual source of trouble since startup.

BENEFITS

The use of the Bird-Pannevis filter will increase overall production without an increase in facilities requirements. In addition to utilizing production facilities more efficiently, the use of the filter reduces the total amount of explosive in Building E-4 at any given time, thereby increasing the safety factor.

IMPLEMENTATION

The Bird-Pannevis Filter has been installed in the production facilities at Holston AAP.

MORE INFORMATION

Additional information on this project is available from Mr. S. Dollman, ARRADCOM, AV 880-3717, or Commercial (201) 328-3717.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project 578 4288 titled, "Explosive Safe Separation and Sensitivity Criteria," was completed by the US Army Armament Research and Development Command in December 1980 at a cost of \$604,000.

BACKGROUND

This project is a continuation of a multi-year effort to develop safety criteria that can be used as a basis for the design of all future explosive production facilities. At the present time, an Army-wide modernization program is underway to either upgrade existing or develop new explosive manufacturing and load-assemble-pack (LAP) facilities. This effort will enable the US Army to achieve increased production cost effectiveness along with improved safety as well as to provide manufacturing facilities for new weaponry with existing facilities. The prior year's effort in FY77 consisted of studies to determine safe separation of explosive end items such as Composition B riser scrap resulting from the LAP of the 105mm M1 projectile. The effort described here will emphasize studies in safe separation distances and sensitivity of explosives and projectiles.

SUMMARY

The objectives of this project were to establish the safe separation of explosive end items in-process materials and establish the sensitivity of explosives at various stages of the manufacturing process to primary and secondary fragment impact. Project accomplishments for this effort were numerous, and the following paragraphs provide examples of work accomplished on specific items and explosives.

155mm M483 HE Projectiles - This test program was performed to determine the safe spacing or shielding necessary between 155mm M483 projectiles to prevent propagation for the HE projectiles under simulated loading plant conditions. The test program was divided into three phases with a total of 100 tests. Phase I consisted of a series of exploratory tests to determine safe separation distance between projectiles contained in a simulated transfer pallet without any shielding (Figure 1). It was concluded from the Phase I configuration tests that the original LAP operational layout for the 155mm M483 HE projectiles could lead to devastating effects if an explosive incident should occur during active line operations at the loading plants. From the tests conducted, it was observed that propagation to detonation reactions in acceptor projectiles occurred at distances far in excess of the 1.5-meter (5.0-foot) guideline distance required for equipment spacing at the loading plants.

In Phase 2, an empty projectile was used as a shield halfway between the donor unit and each acceptor unit. Results indicated that if a separation distance of



Figure 1 - Simulated Pallet With Test Projectiles

0.9-meter (3.0-feet) is maintained between live projectiles using empty projectile bodies as shields between the live ones, the probability of a detonation of adjacent projectiles will be reduced to an acceptable level (9.1% at the 95% confidence level). However, with the presence of exposed trays of grenades (64 per tray) located immediately adjacent to the various projectile loading stations, the probability of an explosive incident propagating from a detonated grenade spilled by a displaced projectile to a tray of grenades may increase to an unacceptable probability of detonation at the 95% confidence level.

Phase 3 consisted of a series of tests to determine the safe separation distance between projectiles that would provide non-propagation of a detonation and would not allow adjacent projectiles to contaminate the immediate area with scattered and armed grenades. The results of the prototype pallet tests indicated that pallets with 2.5-centimeter (1.0-inch) thick shields can be positioned with 72-centimeter (28-inch) center-to-center spacing between projectiles (zero pallet spacing) without a significant chance of propagation of an explosive incident. Also, the rigidity of the prototype pallet is sufficient to prevent major grenade spills and the resultant hazard of secondary sub-projectile detonations. Based on the results of all the tests, it was recommended that the Phase 3 pallet design (with end shields) be considered as a prototype for an existing line or planned line layout.

Non-Propagation Distance of Flake TNT - The primary objective of this effort was to determine experimentally the safe separation, non-propagation distance between 76.2-kilogram (168-pound) quantities of flake TNT being transported in aluminum tote bins by a conveyor system in an interconnecting building ramp. The data derived was used to establish criteria for container spacing on conveyors, conveyor speeds, and production rates for flake TNT. The test program consisted of two parts, each encompassing an exploratory and a confirmatory phase. In the first part, wood

framed and sided ramps were used to simulate actual interconnecting building ramps; in the second part, the simulated ramps were constructed with steel framing and fiberglass sides. In both cases, the exploratory phase consisted of a series of non-propagation trial and error tests to determine the minimum safe separation distance between aluminum tote bins containing 76.2-kilograms (168-pounds) of flake TNT. The confirmatory phase was implemented to establish statistical confidence in the determined distance. The test results showed that the minimum propagation distance for ramps with wood frames and sides was 15.2-meters (50-feet). At this distance, the probability of an explosive incident is 6.98% at the 95% confidence level. For ramps with steel frames and fiberglass sides, the minimum propagation distance was 18.1-meters (60-feet). The probability of an explosive incident at this distance was 7.11% at the 95% confidence level. Other studies completed under this project included, "Determination of Minimum Non-Propagation Distance of 8-inch M106 HE Projectiles," and "Sensitivity of Molten and Solid TNT Charges to Impact by Primary Steel Fragments."

BENEFITS

This project developed new safety criteria which was integrated into Safety Regulatory Documents (AMCR-385-100) to permit construction of functional and safe munitions manufacturing facilities.

IMPLEMENTATION

The safe separation distance data developed from this project was applied to the 8-inch M106 HE Projectile LAP line at Iowa AAP. Ramps with steel frames and fiberglass sides were used on the continuous composition B production line at Holston AAP with the recommended safe separation distances as determined by this project.

MORE INFORMATION

Additional information on this project is available from Mr. R. Rindner, ARRADCOM, AV 880-3828 or Commercial (201) 328-3828.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 575 4310, 576 4310, and 577 4310 titled, "DMSO Recrystallization of HMX/RDX," was completed by the US Army Armament Research and Development Command in September 1978 at costs of \$461,000, \$400,000, and \$200,000, respectively.

BACKGROUND

One of the steps in the manufacture of RDX/HMX at Holston Army Ammunition Plant is the recrystallization process. In that process, the RDX/HMX in a water slurry is dissolved in cyclohexanone or acetone, simmered, and recrystallized mainly to remove the occluded acid present in the crystals. Laboratory studies have been conducted under MMT project 569 4107 titled, "Recrystallization and Growth of HMX-RDX," with the goal of improving the recrystallizing process by utilizing a new solvent Dimethylsulfoxide (DMSO). The advantages of the DMSO was its greater solvating power and ability to recrystallize larger quantities thereby yielding greater throughput of product. The project demonstrated that DMSO could be used to successfully recrystallize RDX and HMX. The most promising method of DMSO recrystallization was the Controlled Nucleation Classified Product Removal system (CNCPR). This project was planned to continue the work on the recrystallization process utilizing DMSO.

SUMMARY

The purpose of this project was to develop an improved continuous recrystallization procedure on a pilot scale using DMSO for all classes of RDX and HMX. The plan was to design the pilot scale plant based on the CNCPR system and all support systems. The equipment was procured and installed at Holston AAP followed by test and evaluation of the pilot plant. Concurrent to the design, product acceptability tests were conducted on DMSO recrystallized product in end items. This was required before DMSO recrystallized RDX and HMX could be implemented into production.

The pilot plant as designed consisted of three basic units; (1) an evaporator system, (2) a crystallization system and (3) an explosives, solvent separation system. A flow diagram of the pilot plant is shown in Figure 1. The general process description is as follows: The feed was prepared by mixing crude explosives and DMSO in the slurry mix tank. The mixture was then pumped to the evaporator feed tank and metered into the evaporator/rectifier system. DMSO was concentrated in the evaporator by removing water from the top of the rectifying column. The concentrated DMSO explosives solution (80-90°C) was fed directly into CNCPR system.

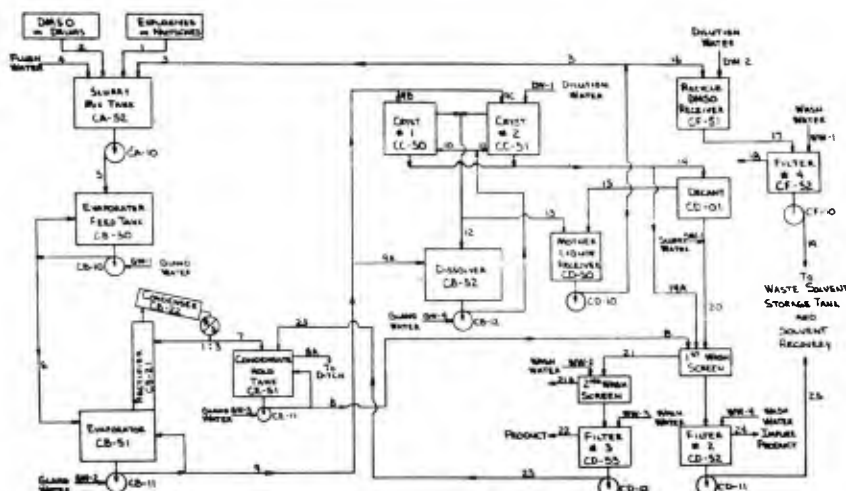


Figure 1 - Flow Diagram of DMSO Pilot Plant

CNCPR system was composed of two crystallizers and a dissolver. Nucleation and growth occurred in the crystallizers when the solution was cooled to 35-45°C. The cooled solution, containing excess nuclei and fines overflowed from the crystallizers back to the dissolver where the fines were dissolved. By manipulating the process variables of temperature, residence times, recycle rates, and product removal rate, the product particle size distribution could be controlled. Water quenching was used to produce fines; whereas, simple cooling produced coarser particles.

Coarse explosives (classes 1, 3, and 4) produced by cooling were removed as a thickened slurry from the crystallizers. The liquid was decanted into the mother liquor and held until it was reused for making new feed solution. The solids were reslurried with water and fed to the first wash screener. The bulk of the product crystals overflowed onto the second wash screen and final product was collected after vacuum filtering.

Fine explosives (class 5) produced by water quenching techniques were removed from the crystallizers in a slurry and metered directly into two vibrating screeners. The product solids were collected in vacuum filters, washed, dewatered and placed in product containers.

On the basis of this process design concept, equipment was procured and building C-6 at Holston AAP was modified for installation of the pilot plant. Equipment installation was completed in September 1978. The start-up, initial operation and evaluation of the pilot plant was completed in the follow-on MMT projects of FY78 and FY79.

Performance tests were conducted on end items loaded with both RDX and HMX recrystallized from DMSO and those loaded with standard RDX and HMX. Detonators, leads and boosters were loaded and tested at Lone Star AAP and warheads were loaded and tested at Yuma Proving Ground. No significant difference was observed between RDX/HMX recrystallized from DMSO or the standard solvents (acetone and cyclohexane).

BENEFITS

The scale-up of the laboratory process to a pilot plant scale provides a means of confirming the DMSO recrystallization process data and serves as the basis for designing a full-scale production facility.

IMPLEMENTATION

The pilot plant for the recrystallization of RDX/HMX from DMSO will be operated and evaluated in the follow-on MMT projects 578 4310 and 579 4310.

MORE INFORMATION

Additional information on this project is available from Mr. R. Goldstein, ARRADCOM, AV 880-4122, or Commercial (201) 328-4122.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects 578 4310 and 579 4310 titled, "DMSO Recrystallization of HMX/RDX," was completed by the US Army Armament Research and Development Command in January 1981 at costs of \$196,000 and \$483,000, respectively.

BACKGROUND

This effort is the continuation of the development of a pilot scale process to continuously recrystallize RDX/HMX from dimethylsulfoxide (DMSO). The use of this improved process would allow more efficient crystallization of large quantities of RDX/HMX in minimal time thereby yielding significantly greater throughput of product. In a previous year, (FY75) project, product acceptability tests on small quantities of DMSO recrystallized product were conducted along with end item tests at Lone Star AAP and Yuma Proving Ground. No significant differences were found between DMSO recrystallized RDX/HMX and standard RDX/HMX. During the FY75, FY76 and FY77 efforts, the design, procurement and installation of the pilot plant was accomplished. In addition, a hazard analysis on the equipment and operations of the pilot plant was performed.

SUMMARY

This project involved the startup and initial operation of the DMSO pilot plant at Holston AAP. Sufficient quantities of DMSO recrystallized RDX/HMX were to be produced for testing of end items loaded with Composition B, A Compositions, Cyclotols, and Octols.

The test and evaluation of the pilot plant involved several tasks. Initially, inert runs were performed to debug the equipment. These runs were followed by prove-out runs with the live material to establish process parameters and, finally, followed by an endurance run of selected duration.

Evaluation of the pilot plant began with the individual equipment tests of the evaporator/rectifier column, the crystallizers and the product wash screeners. These tests resulted in a number of deficiencies being noted and subsequent corrective actions being taken. After appropriate modifications, the pilot plant equipment was able to function in an acceptable manner.

Continuous operation of the complete pilot line was successfully demonstrated. All planned classes of both RDX and HMX were produced although a few additional process modifications had to be made in order to obtain certain classes. In order to obtain Classes 3 and 4 of RDX, material leaving the evaporator had to be introduced directly into the crystallizers rather than first into the dissolver. Trial and error led to development of appropriate values for temperature, feed rate and product removal times under this modified configuration. For Class 1, the fines removal circulation loop between the crystallizer and the dissolver had to be eliminated. Class 5 RDX, which requires dilution crystallization, was obtained,

but only after a change was made which enabled batch-wise operation. For all classes of material, it was also necessary to remove the first product screener and use instead, a decant procedure for the initial separation of product crystals from spent mother liquor. In all, close to 3900 lbs. of RDX were produced. Although throughput varied with the particular class being recrystallized, a maximum instantaneous rate of 50 lb/hr was reached (for nominal Class 1 RCX) which is 2.5 times design rate.

Initial attempts at continuous recrystallization of HMX larger than Class 1 proved unsuccessful. Variation of all parameters associated with the performance of the crystallizers had no effect on produce size distribution (PSD). However, when material leaving the evaporator was introduced directly into the crystallizers, Class 3 HMX was produced with good repeatability. Production of Class 5 HMX by water dilution initially resulted in a material which met the PSD requirement but contained a high percentage of the alpha and delta polymorphs. These materials are more sensitive than the beta polymorph which is the desired product. The pilot study was halted and a laboratory investigation was carried out which led to a procedure in which the dilution water was first seeded with beta HMX. This method was then tried in the pilot plant with satisfactory results. Pilot plant runs concluded with a successful 120 hour endurance run during which the primary products were Class 4 and Class 1 HMX. Switching between classes was accomplished "on the fly," thus demonstrating the flexibility of the continuous process. Earlier, problems with insensitivity of the process to changes in operating parameters were found to be due to the process not being permitted to reach equilibrium. In all, approximately 2000 lbs. of HMX were produced.

Pilot plant cleanup and decontamination were performed prior to execution of the next phase of the program which will involve preparation and testing of explosives formulated from the DMSO-recrystallized RDX and HMX. The qualification and end item test program will be performed in the FY80 project.

BENEFITS

The continuous operation of a pilot plant for DMSO recrystallization of RDX/HMX was successfully demonstrated. All planned classes of both RDX and HMX were produced, although additional process modifications had to be made in order to obtain certain classes.

IMPLEMENTATION

Implementation of the DMSO process improvement is contingent upon completion of additional process studies and satisfactory results of the qualification end item testing in the FY80 project.

MORE INFORMATION

Additional information on this project is available from Mr. R. Goldstein, ARRADCOM, AV 880-4122, or Commercial (201) 328-4122.

Summary Report was prepared by Peter Martin, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY

PROJECT SUMMARY REPORT

(RCS DRCMT-302)

Manufacturing Methods and Technology projects 577 4343 and 578 4343 titled, "Improved Nitrocellulose Process Controls," were completed by the US Army Armament Research and Development Command in April 1980 at costs of \$296,300 and \$15,000, respectively.

BACKGROUND

Cotton linters and woodpulp are sources of cellulose feedstock for nitration with mixed acids into the nitrocellulose (NC) used for manufacture of propellant. The more uniform cellulose from cotton linters is preferred, but woodpulp cellulose is less expensive with abundant supply for mobilization. In the 1950's, woodpulp cellulose characteristics and specifications were established for batch nitration processes on the then available sulfite and prehydrolyzed sulfate woodpulp. Technological advances to the continuous nitration process and continuous automated propellant lines and changes in the availability of types of sulfate woodpulp indicated the need for more effective updated process controls. ARRADCOM and Radford AAP jointly executed this MMT effort by characterizing NC from an expanded variety of woodpulp and evaluated variables in the continuous nitration process.

SUMMARY

Detailed laboratory experiments were conducted by ARRADCOM on woodpulp samples to identify and evaluate woodpulp variables which affect nitrocellulose characteristics. Fiber species of oak, gum, poplar, pine, spruce, fir, cedar and European softwood were covered. Fourteen types (11-sulfate, 3-sulfite) of processed pulp were analyzed for chemical and physical characteristics such as empirical indices, carbohydrate fractions, viscosity, weight, density and fiber length. The woodpulp samples were prepared, nitrated, stabilized and characterized under controlled conditions and procedures. The variables that affected NC characteristics were found to be material sheet density, degree of polymerization, type of pulping process and type of cellulose crystal lattice.

Radford AAP evaluations with the continuation nitration process covered a literature review, laboratory investigations and in-process characterization of NC throughout the system. Twenty-seven (27) samples of NC were analyzed for nitrogen content using mercury nitrometer and titanous chloride titration methods. Results from the nitrometer were generally lower. Data comparison of nitrogen levels with the woodpulp characteristics of alkali solubility, Mullen Burst Strength and moisture showed no correlation. The 27 samples of NC and 18 wood pulp samples were examined microscopically. Viscosities of the 18 wood pulp samples were also determined. Figure 1 is a typical photograph of woodpulp fibers. Acid absorption rates and nitration characteristics of the cellulose varied with the source of the pulp and the pulp treatment process.

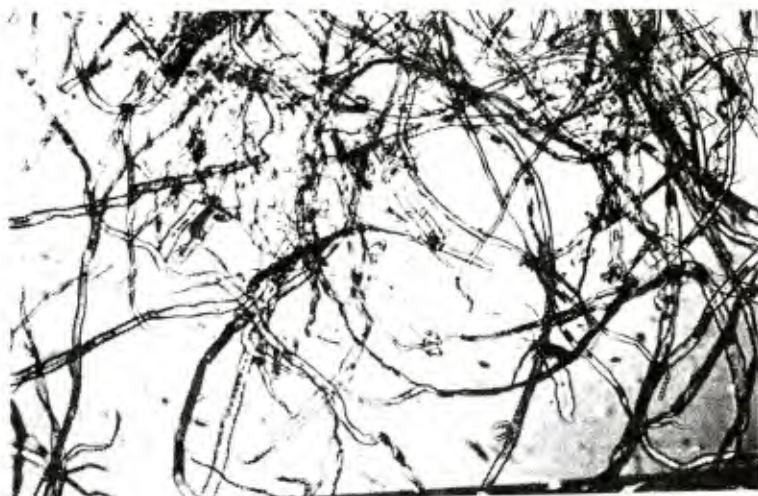


Figure 1 - Typical Woodpulp
Microphotograph (100X)

A series of in-process samples were taken to characterize the continuous improved nitrator (CIN) process. Samples were analyzed from nitrating vessels, the mixing scale, Merco filters and centrifuge wash tanks. The NC was separated, washed with water, stabilized in water and analyzed in the laboratory. Acid samples were also evaluated. The data indicated that the point of complete nitration varied with the type of cellulose used, the grade of NC manufactured and the acids used. However, the end product NC was not significantly affected by nitrations using hardwood pulp, sulfate-processed coniferous woodpulp and sulfite-processed coniferous woodpulp.

BENEFITS

Evaluated technical data was obtained on additional woodpulp types, in-process controls and end product nitrocellulose. Improved process control parameters were identified for nitration of cellulose.

IMPLEMENTATION

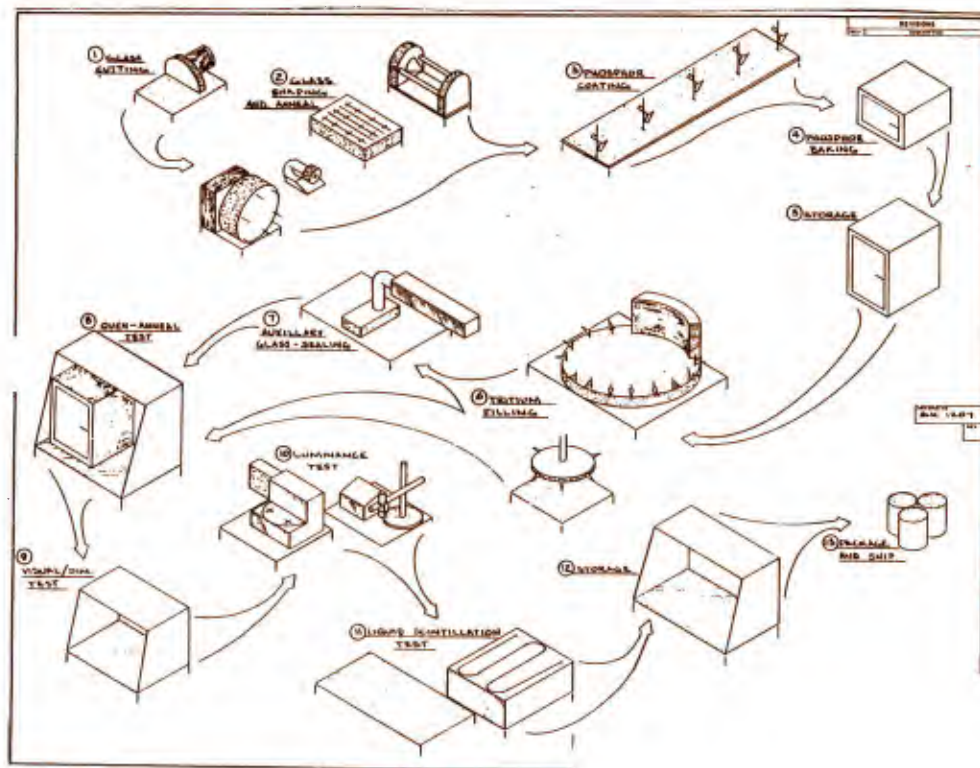
Results are being incorporated into current test procedures and nitrocellulose manufacturing processes at Radford AAP.

MORE INFORMATION

Additional information on these projects can be obtained from Mr. Wendell Leach, ARRADCOM, AV 880-3836 or Commercial (201) 328-3836. Contractor report ARLCD-CR-80029 titled, "Improved Nitrocellulose Process Controls," was published by ARRADCOM in December 1980. Distribution is limited to US Government agencies only because of proprietary information.

Summary Report was prepared by Jim Weintraut, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

NON-METALS



SELF-LUMINOUS LIGHT SOURCE PROCESS

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology projects E78 3613 and E79 3613 titled, "Vehicle Mounted Road Mine Detector System Antennas," were completed by the US Army Mobility Equipment Research and Development Command in June 1980 and December 1980, respectively, at a total cost of \$326,000.

BACKGROUND

Corner reflector antenna modules are currently utilized in the vehicle-mounted mine detector system. The module configuration is shown in Figure 1. The system must be capable of detecting buried plastic and metallic anti-tank mines. It detects mines by transmitting radio frequency (RF) signals into the ground and analyzing the return signals reflected from below the surface. The RF signals are transmitted and received through an antenna array in the search head, mounted at the front of a search vehicle and made up of ten individually articulated antenna modules. These ten modules are vulnerable to damage from obstructions in their path; therefore, they must be low in cost and easy to replace in the field.

The materials currently used are expensive due to the number and size required to construct an antenna. The current production techniques, which are basically all manual, represent a cost of approximately \$350 per antenna module.

SUMMARY

The objectives of these projects were to investigate, apply, and evaluate available processing and manufacturing techniques with the aim of producing an effective, yet inexpensive, antenna module. The basic area of investigation was on production techniques for the antenna assembly which comprises the body of an antenna module. The investigation of production designs included evaluation of metalworking, foaming, fiberglass, and plastic molding fabrication techniques. The goal was to produce an antenna module that would meet the operational requirements and would cost approximately \$50.

Six metal fabrication processes were considered for use in manufacturing various components of the antenna assembly from sheet metal. These techniques included stamping, roll forming, hydro-forming, deep hammer shaping, extrusion, and super-plastic metal thermoforming. High tooling costs and/or limited application eliminated all but the stamping and super-plastic thermoforming as viable metal fabrication processes.

Thermoforming, rotational molding, and injection molding were plastic fabrication processes studied for producing portions of the antenna module. Of these, rotational molding was the most feasible plastic fabrication process.

The foam-in-place fabrication concept has disadvantages that far outweigh the advantages. Just to name two of them, the high cost of the foam and the marginal weight make this concept unacceptable as a production method.

Two methods of production were investigated for fabrication of the antenna assembly using fiberglass. These were the matched mold method and the chop gun method. In both methods, the thickness of the fiberglass material can vary considerably, not only from part to part, but also within an individual part itself. This variance of thickness would make the assembly weak in thin areas, thereby decreasing the overall life and reliability of the assembly. Therefore, this approach was dismissed from further consideration.

Several factors such as cost, weight, ease of assembly, reliability, and number of component parts were considered in determining the most desirable of the alternative fabrication techniques. The rotational molding technique was recommended for production of a hollow, one-piece antenna assembly that would incorporate the covers, end guards, and support bar assembly. The design recommended is shown in Figure 2.

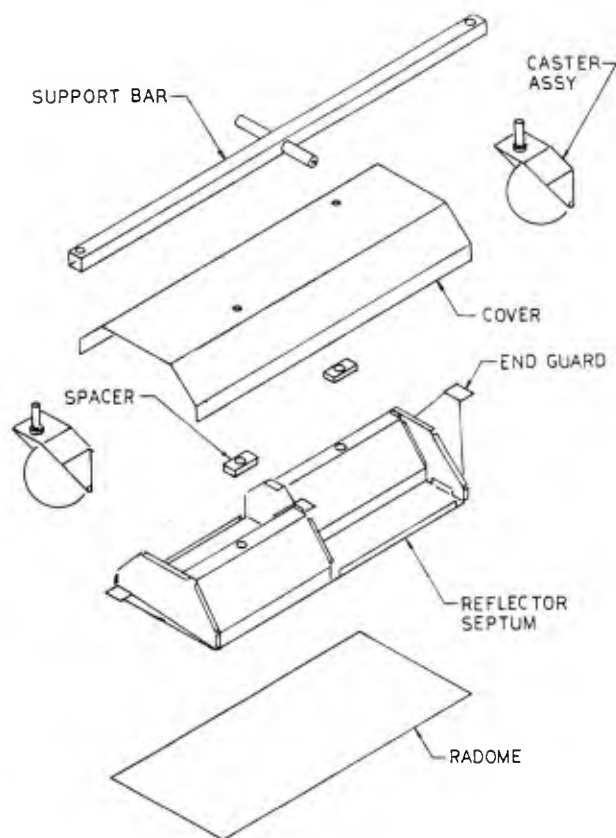


Figure 1 - Existing Antenna Module

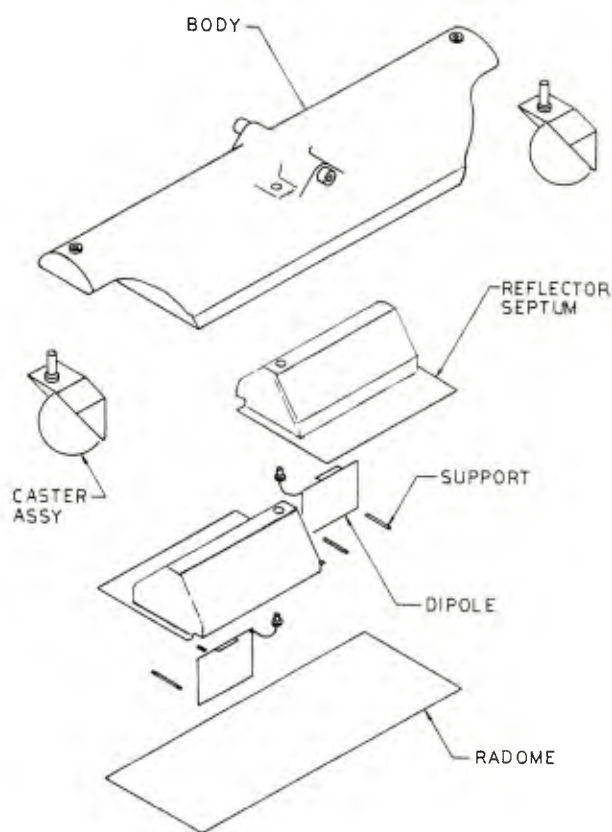


Figure 2 - Recommended Antenna Module

BENEFITS

The projects resulted in manufacturing techniques and procedures which will reduce the cost of each antenna module. The cost of the recommended antenna module is estimated to be \$95 as compared to the current unit cost of approximately \$350.

IMPLEMENTATION

The antenna hardware is scheduled to be accepted for production in 1981; therefore, the implementation of the results of these projects will be held in abeyance until that time.

MORE INFORMATION

To obtain more information, contact the project officer, Mr. Guy Origlio, MERADCOM, AV 354-4498 or Commercial (703) 664-4498. A final report titled, "Evaluation of Potential Antenna Module Fabrication Techniques for the Vehicle-Mounted Road Mine Detector System," was published by Cubic Corporation on 3 November 1980.

Summary Report was prepared by Bob Hellem, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

MANUFACTURING METHODS AND TECHNOLOGY
PROJECT SUMMARY REPORT
(RCS DRCMT-302)

Manufacturing Methods and Technology project R76 3076 titled, "Mass Production Techniques for Composite Rocket Motor Components," was completed by the US Army Missile Research and Development Command in April 1977 at a total cost of \$250,000.

BACKGROUND

The Army, in an effort to improve the performance of future land combat rocket systems, conducted research to reduce the weight of these systems. One of the areas showing potential was the propulsion system. Fiber reinforced plastic composites such as fiberglass/epoxy, graphite/epoxy and Kevlar-49/epoxy were used to fabricate motors in small batch quantities. In subsequent tests, these motors exceeded mission requirements. Unfortunately, the unit costs to fabricate these motors is much higher than the current metallic production models in lieu of a composites production level manufacturing process.

The purpose of this project is to establish a production scale manufacturing process for composite rocket motors in which they can be produced at a rate of over 10,000 units per month and at a unit cost 20% less than the cost of the current, monolithic metal motors.

The project was accomplished by contractual effort at Hercules, Inc., Allegany Ballistics Laboratory, Cumberland, Maryland 21502.

SUMMARY

This project carried the production methodology established in R75 3076 (Phase 1) into prototype production (Phase 2). The production run was conducted with a case design that combined the best features of the two case designs considered in the Phase 1 effort. This case was designed to yield the lowest fabrication cost without violating design and performance requirements. It features an integral nozzle, with a fully open forward end that is closed with an end cap held by a metallic adaptor ring. The winding of the case and nozzle was helical (winding angle of 61.5° which resulted in an angle of 43° in the geodesic dome contour) with 90° fill and two 90° layers forward of the adaptor.

The cases were wound on a modified standard EN-TEC type 800 series winding module pictured in Figure 1. Specialized winding equipment added to the basic machine was designed and fabricated for the purpose of increasing winding speed from 100 to 300 rpm. The design also allowed for two double windings (four cases)

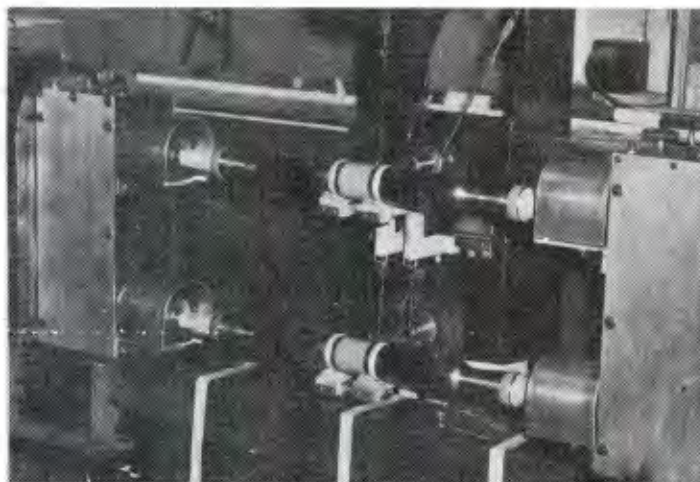


Figure 1 - Winding Machine
With Mandrels in Place

	Production Method from Phase I Study	Simulation Goal in Phase II	Actual Results
Winding Numbers	12 units at a time	4 units at a time	4 units at a time
Roving Speed	150 ft/min, 36 end	150 ft/min, 36 end	216 ft/min, 36 end
Roving Delivery	Wet	Wet	Wet
Resin Mixing and Delivery	Automatic	Automatic, capable of production	Automatic, capable of production
Case Machining	Diamond tipped tool 120 cuts min, 1200 desirable	Cut rings simulating case wall	850 cuts with no sign of tool ware
Case Dimensional Stability (Mandrel Control of Dimensions)	Hold ± 0.001 diameter and 0.002 tip on case ID	± 0.001 diameter and 0.002 TIR	All cases were in ± 0.001 and 0.002 TIR
Resin Impregnation	Transfer wheel	Transfer wheel	Transfer wheel

Figure 2 - Summary of Demonstration and Refinement Results

at a time, for one degree of servo control (3 are available), for rapid installation and removal of the mandrels, and for easy installation and removal of the equipment. All of the equipment was designed in-house except the resin mixing equipment which was available commercially. The winding of two double units rather than the six necessary for economical production was considered sufficient for demonstration purposes.

The project established the techniques for resin mixing, roving delivery and impregnation, and winding and machining of the case. The results are presented in Figure 2. Resin content in selected locations of the case were relatively uniform (30%) except in areas of helical and 90° windings where a content of 20-25% resulted. Winding speed was successfully increased beyond expectations, but required changes in the controlling cams to maintain satisfactory winding patterns. Case machining was conducted with a diamond tipped tool bit at a feed rate of 0.0024-in. per second at 315 rpm. Examination of the tool bit after extensive cutting indicated

an anticipated bit life in excess of 1200 cuts.

The rocket motors were evaluated for weight, dimensional accuracy, and structural integrity. The weight variation was ± 25 grams on the 54 units fabricated. With modification of the technique, standard deviation of 9 grams from the 375 gram case weight is projected in production.

The units were measured immediately and three weeks after hydrotesting. The variation in internal diameter (ID) was out of tolerance immediately after testing but was within limits three weeks later, although the ID increased permanently by 0.0025-inches.

Structural integrity was determined by burst testing. The average failure was 13,095 \pm 577 psi (11,400 psi requirement).

The only critical area considered not fully demonstrated was the ability of the units to maintain drawing tolerance after proof testing. Although the unit dimensional stability could be achieved with a mandrel dimensional change, more study is needed on this aspect.

Evaluation of the prototype production run showed that production man hours were reduced significantly. This was attributed to the increase in filament winding speed and the combining of mandrel removal with the machining step. These factors allowed seven operators rather than the projected eight to operate a line producing 500 units per shift.

BENEFITS

The project was successful, but additional work to stabilize the motor ID, to further reduce winding time, to improve resin impregnation and excess resin control, and to improve adapter holding during winding was deemed necessary.

IMPLEMENTATION

The process demonstrated by this project will be improved upon in follow-on projects R-7T and 77-3076.

MORE INFORMATION

Additional information on this project is available from Mr. William Crownover, MICOM, AV 746-5821.

Summary Report was prepared by Ferrel Anderson, Manufacturing Technology Division, US Army Industrial Base Engineering Activity, Rock Island, IL 61299.

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